

Appropriate wood harvesting in plantation forests

Training materials from the
FAO/Finland Training Course on
Appropriate Wood Harvesting Operations
Mutare, Zimbabwe, 9-26 June 1986

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FOREWORD

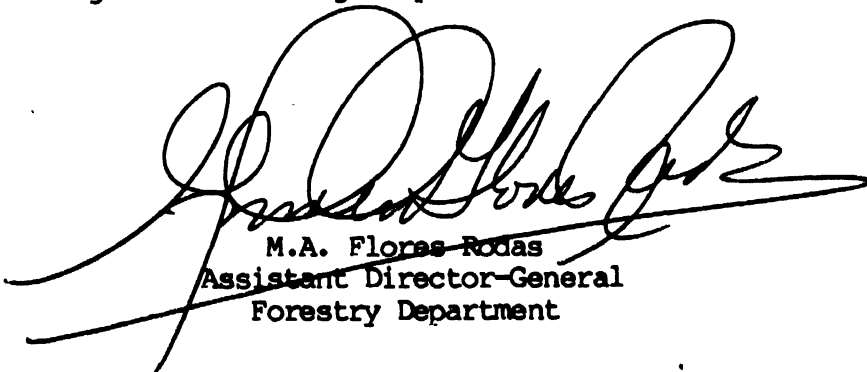
An important prerequisite for a successful forest industry enterprise is the timely and cost-effective procurement of raw material through appropriate wood harvesting, with due consideration of social, technical and economic issues. Some of the factors involved are training, working conditions of the labour, selection of working systems and methods, reduction of post-harvesting losses and the environment.

One of the main difficulties in efficient forest harvesting is the lack of experienced and competent personnel capable of making sound managerial and operational decisions. This usually results in high production costs, increased accident rates and lack of motivation of the forest workers. It also has a negative impact on the effective use of the forest resource base and on the environment.

To improve the capability of forest harvesting personnel, the Forestry Department of FAO is undertaking a series of training courses with the assistance of Finland under the FAO/Government Cooperative Programme.

It is hoped that through publication of these lectures given at the training course on Appropriate Wood Harvesting Operations which was held in Mutare, Zimbabwe, from 9 to 26 June 1986, efforts to improve raw material procurement systems for forest industries will be stimulated and also result in improved utilization of coniferous manmade forests in developing countries.

The Food and Agriculture Organization of the United Nations is much indebted to Finland for sponsoring this training course and looks forward to a continuing and increasing cooperation.



M.A. Flores Rodas
Assistant Director-General
Forestry Department

EDITORIAL NOTE

The papers presented in this report have been edited to the extent considered necessary for the reader's assistance.

The mention of specific companies or of their products or brand names does not imply any endorsement or recommendation on the part of the Food and Agriculture Organization of the United Nations.

Cover Photo: Manual loading of pulpwood onto a semi-trailer to be transported by agricultural tractor.
(Photo: H. Seppänen)

ABSTRACT

The FAO/Finland Training Course on Appropriate Wood Harvesting Operations was held from 9 to 26 June 1986 at Mutare and Troutbeck in Zimbabwe. The training course was sponsored by the Government of Finland and organized by the Forestry Training Programme (FTP) of Finland in cooperation with the Food and Agriculture Organization of the United Nations.

The purpose of the training course was to train logging managers to improve overall efficiency of wood-harvesting operations in developing countries, and to promote analysis and discussion by the participants in order to draw conclusions and make recommendations on the training needs and improvement of wood-harvesting operations. The course was organized also to strengthen existing wood-harvesting training centres in developing countries and in the long term to promote national and regional training centres.

The course placed emphasis on the following aspects of wood-harvesting operations: planning of raw-material procurement; selection of appropriate technology; cost control; forest road construction; felling, bucking, skidding; wood transport; equipment maintenance; safety, ergonomics; log grading and interrelated subjects on the forest resource base and forest industry.

The programme included lectures, excursions, demonstrations, film shows, group work sessions, country reports and practical training.

The course was attended by 29 participants from the following 15 developing countries: Botswana, Cameroon, Ethiopia, Ghana, Lesotho, Liberia, Malawi, Mozambique, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. Seven participants attended from the host country.

The participants included people from private and public forest enterprises and ministries of agriculture and forestry as well as training and research institutions.

This document is a compilation of the lecture papers presented at the training course. It is hoped that many logging managers dealing with the development of appropriate wood-harvesting operations will profit from the information contained in it.



Manual rolling of logs in thinning operations
in a Pinus patula plantation
in steep terrain (Photo: H. Seppänen)

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INTRODUCTION

1. ORGANIZATION AND ADMINISTRATION

The preparatory work and the organization of the FAO/Finland Training Course on Appropriate Wood Harvesting Operations held in Zimbabwe, 9 to 26 June 1986, were carried out in close collaboration between the Forest Industries Division of FAO and the Forestry Training Programme (FTP) of Finland.

The venues of the course were the Manica Hotel in the city of Mutare and Troutbeck Inn in the Manicaland province. The excursions were in the vicinity of the cities of Mutare, Nyanga and Penhalonga.

Mr. Rudolf Heinrich of FAO was appointed course director. Mr. Esa Hurtig of FTP and Mr. Ian MacLennan of the Zimbabwe Forestry Commission were co-directors.

In addition, four expatriate and two local lecturers as well as twenty excursion leaders contributed to the programme.

Administrative, technical and secretarial assistance was provided by the Zimbabwe Forestry Commission, Zimbabwe College of Forestry and FAO.

2. PARTICIPANTS

The training course was attended by 29 participants from 15 developing countries in Africa: Botswana, Cameroon, Ethiopia, Ghana, Lesotho, Liberia, Malawi, Mozambique, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda, Zambia and Zimbabwe.

All 29 participants were sponsored by the Government of Finland.

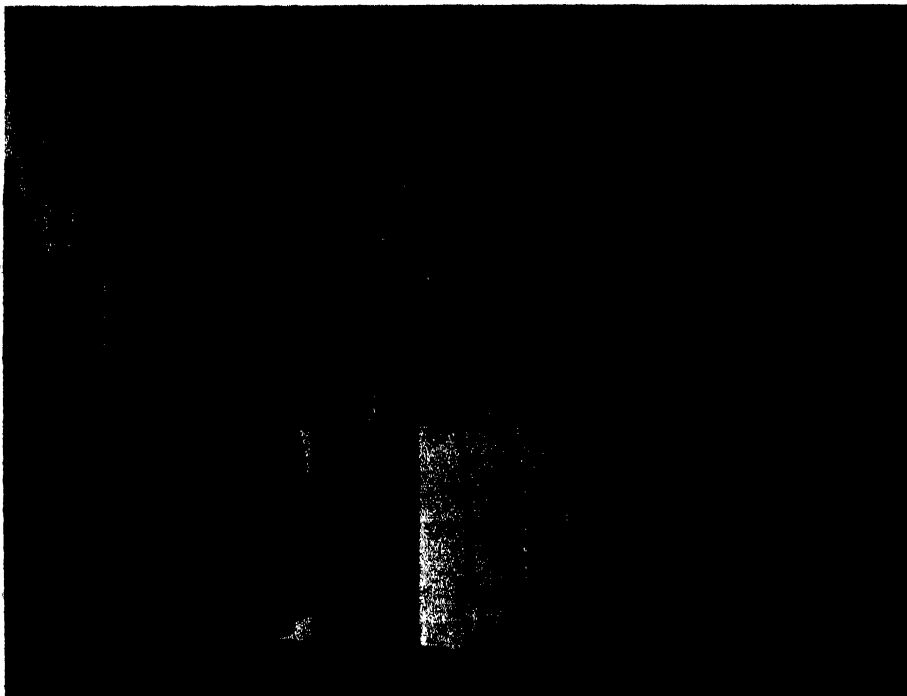
The participants were mainly from public and private forest enterprises and ministries of agriculture and forestry as well as training and research institutions.

3. PURPOSE OF THE COURSE

The purpose of the course was to train logging managers to improve overall efficiency of wood-harvesting operations in developing countries and to promote analysis and discussion by the participants in order to draw conclusions and make recommendations on the training needs and improvement of wood-harvesting operations. The course was organized also to strengthen existing wood-harvesting training centres in developing countries and in the long term to promote national and regional training centres.

4. PROGRAMME

Mr. A.V. Todorov opened the course on behalf of the FAO Representative, Mr. K.E. Kolding, and welcomed the participants to Zimbabwe.



The Hon. Mrs. V.F. Chitepo, MP, Minister of Natural Resources and Tourism, welcoming the participants, Monomatapa Hotel, Harare (Photo: H. Seppänen)

On behalf of the Government of Finland, Mr. Esa Hurtig, Training Manager of FTP and co-director of the course, welcomed the participants.

Mr. Rudolf Heinrich, FAO director of the training course, in his introductory address welcomed the participants on behalf of Mr. M.A. Flores Rodas, Assistant Director-General, Forestry Department, FAO, Rome.

The Hon. Mrs. V.F. Chitepo, MP, Minister of Natural Resources and Tourism, in her welcoming address expressed her satisfaction at Zimbabwe's having been selected to host the training course.

The course programme included lectures, excursions, demonstrations, film shows, group work sessions, country reports and practical training.

It placed emphasis on the following aspects of wood-harvesting operations: selection of appropriate technology; cost control; forest road construction; felling, bucking, skidding; wood transport; equipment maintenance; safety, ergonomics; log grading; and interrelated subjects on the forest resource base and forest industry.

The excursions were prepared to demonstrate raw-material procurement of a small-, a medium- and a large-scale sawmill. In addition, excursions were made to the training facilities of the Zimbabwe College of Forestry and to observe harvesting, grading and treatment of transmission poles, charcoal production and chemical forest industries.

Particular emphasis was placed on the selection of appropriate logging technology by making detailed cost and production calculations of alternative methods and by discussing the socioeconomic implications of different options.

Practical training was carried out in forest road location by demonstrating the surveying instruments and staking the road alignment in the forest as well as discussing the additional equipment necessary when surveying on steep terrain.

The participants presented country reports including a country introduction, main features of forestry, forest resources, forest industries, logging, and road construction. Main problems and constraints in logging development were also discussed.

At the end of the course the draft report including conclusions and recommendations was reviewed and adopted by the participants.

At the closing ceremony, the Minister of Natural Resources and Tourism, the Hon. Mrs. V.F. Chitepo, MP, presented the participants with course certificates.

5. CONCLUSIONS

The participants agreed as follows:

1. The lectures provided a sound basic introduction to appropriate wood-harvesting technology, working methods and management practices.
2. The excursions provided an excellent opportunity to see appropriate plantation harvesting technology as practised in Zimbabwe. Of particular value was the opportunity to see on a commercial scale, felling techniques using hand tools, manual, animal and agricultural tractor skidding, efficient manual loading techniques, transport by agricultural tractors and trucks, and simple and efficient truck and trailer unloading devices. The excursions also included the opportunity to visit various processing operations for sawn timber, pole, pulp and paper production, and charcoal. Various systems to increase worker motivation and productivity were observed, including the use of incentives and bonuses.
3. The practical field exercises demonstrated the techniques and value of work studies in evaluating work methods and systems. A trial demonstration of the sulky showed that a simple wheeled device could have a positive impact on manual forwarding in plantation forests. The field exercises in road location demonstrated the necessity of road planning to achieve infrastructure objectives. Participants recognized the importance of using simple surveying instruments in achieving a proper forest road network to develop forest resources.
4. The training session provided an important opportunity for foresters in neighbouring countries to exchange views and have constructive dialogue on common forestry problems. It also provided an opportunity to establish valuable future contacts for information exchange.



The Hon. Mrs. V.F. Chitepo, MP, Minister of Natural Resources and Tourism, welcoming the participants, Monomatapa Hotel, Harare (Photo: H. Seppänen)

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4. The training session provided an important opportunity for foresters in neighbouring countries to exchange views and have constructive dialogue on common forestry problems. It also provided an opportunity to establish valuable future contacts for information exchange.

6. RECOMMENDATIONS

The participants recommended the following:

1. Based on the experience of this course, periodic follow-up courses should be held to reach a larger segment of the forest and harvesting industry in the African region.

2. Follow-up courses should include training in effective methods of harvesting and infrastructure development to enhance employment opportunities for the rural people in forest operations and promote their income as a means to reduce the pressure on forest land.

Training in appropriate harvesting methods should be extended to natural forests under various terrain and soil conditions. The harvesting methods should consider the reduction of wood waste and fuller utilization of the forest resource base. Urgently needed infrastructure-development training in road planning and construction methods suited to the socioeconomic conditions in developing countries should be given.

3. Given the importance of cost calculations in assisting managers to make harvesting decisions, more emphasis should be put on cost control in selecting equipment and machinery in forest harvesting.

4. Case studies should be undertaken to document the various harvesting systems that are being successfully applied in Africa under different working conditions. There should be particular emphasis on those systems which have been most efficient in meeting socioeconomic goals: manual felling, animal skidding, manual loading, transport by agricultural tractor and trailer, and simple gravity unloading trailers.

The results of the case studies and training courses should be made available in the form of technical reports in order to reach as broad an audience as possible. This should assist log production managers to improve wood-harvesting systems and techniques in the region.

5. Information should also include how to manufacture appropriate hand tools and basic equipment to improve manual and semi-mechanized harvesting operations locally.

THE TIMBER INDUSTRY IN ZIMBABWE

by

K. Radford
President, Timber Council of Zimbabwe

The Timber Council of Zimbabwe was formed in 1982 out of what had been the Timber Promotion Council which came into being in 1972. The Council is made up of growers, lumbermillers, timber processors and timber traders. Each discipline elects two members to the Council for a one-year term of office. The President is elected by the Council from among its members for two years.

The Council's constitution lays down the following objects:

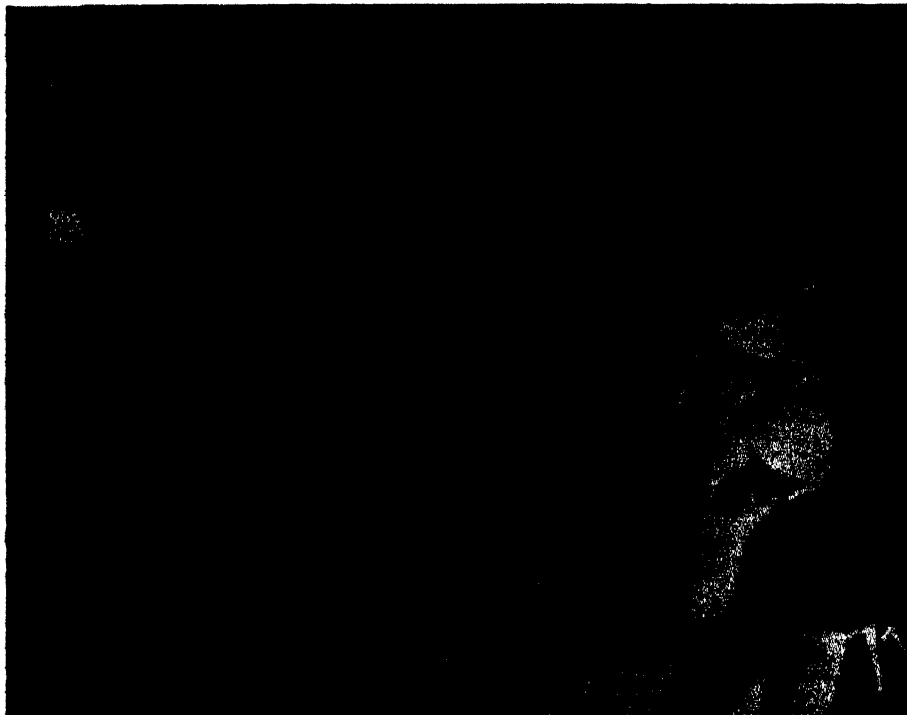
- (a) To encourage and promote the use of timber and timber products;
- (b) To develop and expand both internal and external markets for Zimbabwe timber and timber products;
- (c) To investigate, facilitate and institute methods, plans, systems and forms by which the foregoing objects may be achieved;
- (d) To advance and protect the timber industry in Zimbabwe and interests of all persons connected therewith.

As you can see the Council is very broadly charged with the responsibility of promoting the interests of the industry and those serving it. The Council meets regularly once a month or more often if necessary to plan and organize carrying out the objects of the constitution.

The timber industry of Zimbabwe today provides employment for some 13 000 labourers and if one takes families into account it is not an exaggeration to say that some 70 000 people benefit from the industry. Apart from the labour factor many hundreds of staff - management, professional and technical - are involved in the industry. We have accountants, foresters, sawmillers, mechanics and timber technologists.

If we could go back in time to have a look at what one might call the infancy of today's industry, there is no doubt that it started with the Meikle brothers who, on arrival in the country, planted some Eucalyptus grandis in about 1892. They planted trees on a larger scale in 1904 and in 1923 they set up what was probably the first sawmill in the country. Of their early plantations on Nodzi Farm, just north of Penhalonga, there are still standing some of the eucalyptus trees planted between 1905 and 1910. Members of the Meikle family still live on the farm, still grow trees and still run the sawmill.

In essence, it was private enterprise that initiated plantation forestry in Zimbabwe. It was also private enterprise in the form of the old BSA Company that in 1910 recruited the first forest officer into the country. This was Dr. Sim, whose brief was to look into the overexploitation of the indigenous state forests. As a result of his recommendations Dr. J. S. Henkel was appointed by the Government in 1920. It can be said that the appointment of Dr. Henkel marked



In the Border Timbers sawmill:
one production line using an edger (double circular saw)
for producing sawn timber for boxes and the other line
using a frame saw for structural timber.
The input to the mill was 300 m³ a day in one shift.
(Photo: H. Seppänen)

the start of a State Forestry Department in Zimbabwe. The first venture into commercial afforestation took place at Mtao Forest Reserve in 1923, at a time when little was known locally of the environmental requirements and capabilities of either pines or eucalypts under the semi-arid conditions of that locality.

Dr. Henkel decided initially to test a broad range of both species in the early plantings at Mtao, and the results are in several cases still evident today.

The BSA Company recruited a forest officer for their own plans. This was a Mr. Kleinschmidt, who started planting trees on the Imbeza Forest Estate in 1928. Kleinschmidt was in many ways a farsighted man. He personally surveyed bridle paths over the future plantation area. None had a gradient greater than 3° because he foresaw that in due course each path would be widened sufficiently to take a narrow-gauge railway track. His vision of the future included a role for small steam engines, fired with forest waste, to bring the logs to a collecting point just to the west of the present estate manager's house. From there, he again personally surveyed an aerial cable route over the Cecil Kop range to the railhead at Mutare. That was where, in his view, the logs were to be sawn and processed.

At the time, the BSA Company were not a little alarmed at the growing capital outlay Kleinschmidt's plans were bound to incur in the future, but I am sure that present-day foresters and estate managers would consider it a boon indeed for any estate to escape fuel costs. In the event, Kleinschmidt did not live long enough to see any of his dreams fulfilled, nor to realize that in one respect he had made a serious mistake, for he planted practically the whole of Imbeza to the wrong species - Portuguese cypress. Many years later they all had to be clear felled with little profitable return.

It was not until 1928 that the Government started to acquire land in the area most suited to large-scale softwood afforestation, in the eastern districts of Zimbabwe. They began planting on Stapleford Forest Reserve in 1929. The species chosen were Pinus patula, P. radiata, P. elliottii and P. taeda. Only one of these turned out to be a failure; radiata was affected with diplodia and had to be clear felled.

Another personality who was closely connected with forestry and who possibly did more to promote the industry than any other single individual was Mr. A.C. Soffe, who came to the eastern districts as general manager of the Mutare branch of Meikles' department store before the second world war. He saw the potential for softwood afforestation of the district and involved himself personally almost immediately. He bought Border Farm which adjoined Meikles' Farm, but lay in Mozambique. It was not long before he started planting trees. He formed a company which was initially known as Border Farms and later became Border Timbers. With developments which have taken place since, the present company of Border Timbers represents the biggest forestry investment in the private sector of the timber industry.

It was only after the second world war that large-scale development of both plantation areas and timber utilization took place. Once again Mr. Soffe gave a lead to the country. Through the Mutare Publicity Association, which he had formed to encourage investment in the eastern districts, he promoted forestry in particular. He was involved in persuading Government and private enterprise, including the Wattle Company, that plantation areas must be extended for the benefit of the future. One has only to look at some of the statistics for the post-war years to see how successful his promotion of forestry was. For instance, in 1950 our total plantation area was some 17,000 hectares. By 1960 it had jumped to 65,000 hectares. The plantation area has been increasing ever since, and today's figure is probably 100,000 hectares.

Let me now turn to the utilization side.

I mentioned that the Meikle family started sawmill operations in 1923. No doubt other sawmills started up in other parts of Zimbabwe in due course, particularly dealing with our indigenous hardwoods. It must be remembered, however, that Meikles' were dealing with logs procured from their own plantations.

The next significant development in the use of locally grown softwoods was the production of matches and matchboxes in 1937 by the Lion Match Company. However, a portion of their hardwood requirements (poplar) had to be imported.

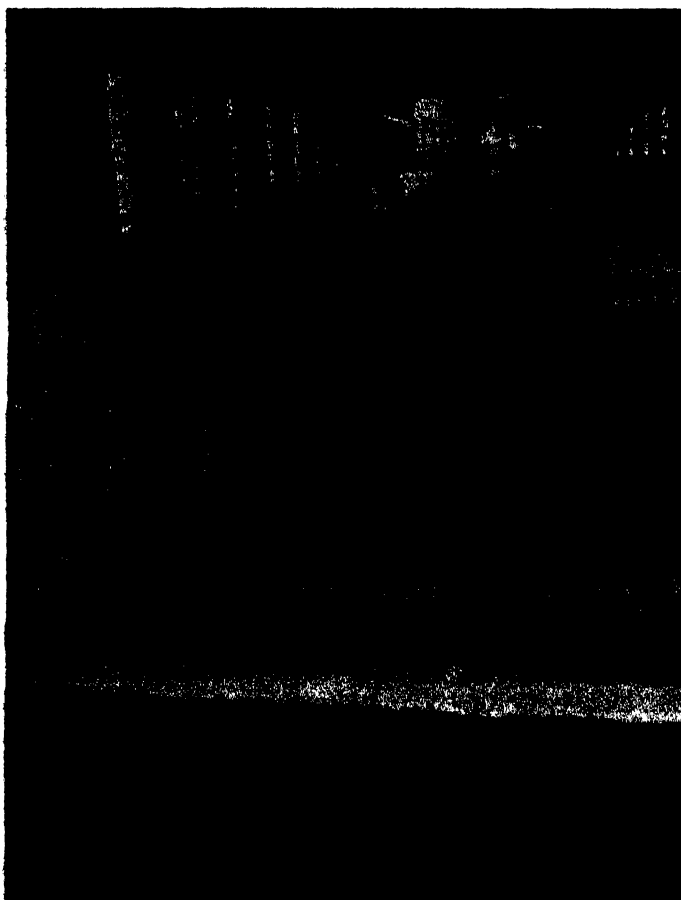
The first state-owned sawmill came into operation on Stapleford Forest Reserve in 1940 and was followed by a second mill in 1947. These mills were closed in 1952 when a large modern mill was constructed. Although this mill was virtually destroyed by fire in 1960, its replacement is essentially the present-day mill at Stapleford.

The Commission's sawmill operations were expanded by the establishment of a mill in the Chimanimani area in 1965 and another in the Nyanga area in 1970. In 1966 the Commission introduced the lamination and finger-jointing process into Zimbabwe, to utilize the relatively large volume of small-dimension sawn softwood timber produced by their sawmill and to service the market for structural timber.

In the private sector of the industry, primary processing facilities expanded rapidly from the late nineteen fifties. The Anglo-American Corporation became the major operator, with sawmills operating on Sheba, Imbeza, Tilbury and Charter Estates.

In 1963 a company began manufacturing plywood in Mutare, and in time expanded its operation to produce blockboards, veneers, laminated beams and finger-jointed timber.

In the pulp, paper and paperboard field, Mutare Board and Paper Mills started operations in 1952 with its mechanical pulp and paperboard mill, utilizing coniferous pulpwood and imported chemical pulp.



The Mutare Pulp and Paper Mill, the main producer of cardboard (1000 tons/month) and the only newsprint producer (1500 tons/month) in Zimbabwe. The roundwood consumption of the mill is about 4500 m³/month.
(Photo: H. Seppänen)

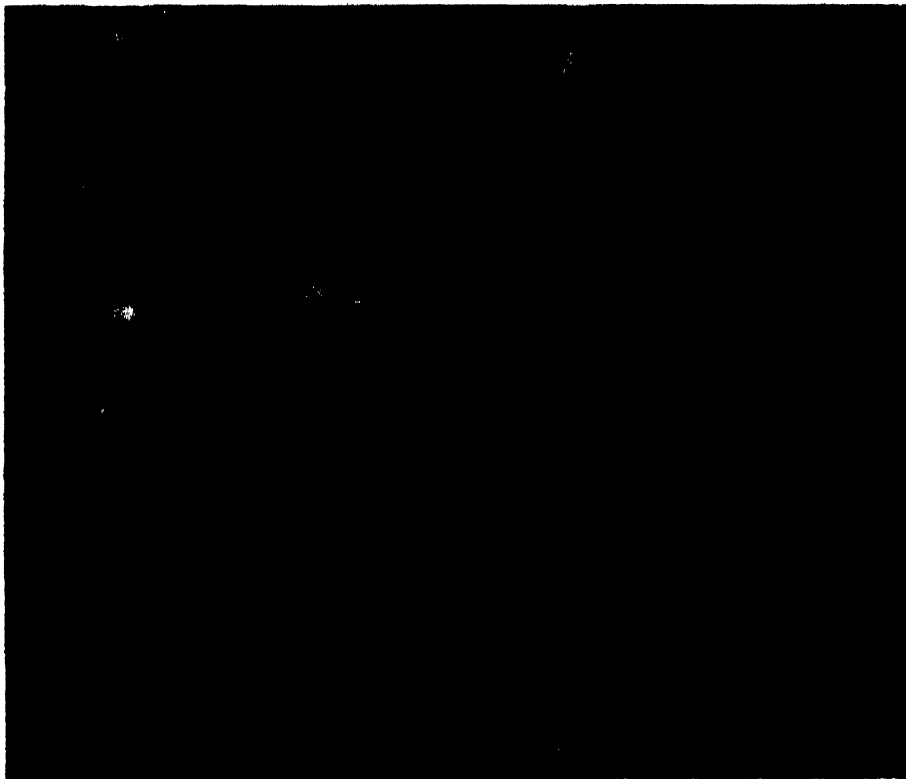
The Hunyani Pulp and Paper Industry's semi-chemical pulp and paperboard mill was established in the late nineteen sixties, utilizing eucalyptus pulpwood drawn mainly from its plantations in the midlands.

More recently (1982), a tissue mill utilizing waste paper and imported chemical pulp was established near Kadoma.

Today in Zimbabwe the industry has in the primary processing sector a match factory, two veneer mills, some 40 sawmills, three pulp mills, two particle board plants, laminating and finger-jointing plants, six pole impregnation plants and a charcoal producing enterprise.

Perhaps the two most vital aspects of the industry lie in research and training. The Research Branch of the Forestry Commission was formed in 1948 to control and coordinate all forest research. In 1960 the John Meikle Research Station was opened and the Research Station in Chimanimani opened in 1962.

Private enterprise has always left research in the hands of the state, which is perhaps the correct place for it.



Unloading the wood (black wattle)
for charcoal making. (Troutbeck Sawmill Ltd.)
(Photo: H. Seppänen)

Our Research Branch has in fact done outstanding work and serves the needs of the whole industry, both Government and private. Its greatest contribution has been the building-up of improved seed in the main pine species, which in turn has led to an increase of wood yield by some 25 percent. The availability of this improved seed is now sufficient to meet the industry's present needs but Canadian aid funding is being used to expand the programme so that research in this field will be of benefit to the whole SADC region. The industry is proud of the work done by the Research Branch. It has drawn international recognition for progressiveness.



Two portable metal kilns used for making charcoal.
The one in front has just been loaded and the
other has just been opened after processing.
In the background, black wattle being unloaded
for burning. (Troutbeck Sawmill Ltd.)
(Photo: H: Seppänen)

Training was at one stage rather the Cinderella of forestry. In the early years foresters and forest officers were recruited from overseas or South Africa. The establishment of plantations was on a scale small enough to be undertaken by a forester supervising a gang of labourers. The Government employed one forest officer and the BSA Company another. It was only after the second world war that the growing need to train our own foresters in Zimbabwe became apparent.

The rapidly expanding Forestry Department initiated a two-year diploma course which was started at Mtao in 1946. This was followed by a second course in 1951. Thereafter the number of replacement foresters required by the industry

was too small to warrant further diploma courses. The very real need for trained men to replace the old foreman type loomed, however, and the Forestry Commission, as it had then become, ran special one-year forest ranger courses, again at Mtao, from 1966 onward. Mtao became in fact the forest training centre until its closure in 1973.

The benefits of having trained men in supervisory positions highlighted a new facet within the industry, and that was the urgent need to train all workers, even the unskilled. Consequently the nineteen seventies saw a steep upward trend in training programmes. Private enterprises no longer looked to Government to meet their training needs but initiated their own training programmes.

Training schools were started on private estates, where workers were given induction courses as well as courses on first aid, safety, tool maintenance, and so on.

The Forestry Commission resumed the one-year forest ranger training course in 1977, at a new site in the Imbeza Valley, which they called the Nyabara College of Forestry. The two-year forest diploma courses were re-started in 1981.

The Zimbabwe College of Forestry today is not only meeting the training requirements of our own forest industry, but is also open to members of SADCC countries. The college has a broad spectrum of short courses which are tailored to suit the industry. Consequently private enterprise now provides in-house training only and is happy to support the Zimbabwe College of Forestry in its efforts to meet training requirements. There are two main areas where obviously the college cannot cope on its own. These are harvesting and sawmilling. The present FAO/Finland Training Course on Appropriate Wood Harvesting Operations will fill a gap and we are grateful for the effort.

The trading and processing of timber started early in this century, mainly with the importation of timber in the length for roofing or else prepared shooks for the assembly of timber products. Tobacco was packed in hogsheads assembled from imported shooks in the late twenties and early thirties. In time, imported timber replaced imported shooks and by the nineteen fifties local timber replaced imported timber. Now our processing industry is capable of producing any timber products - pallets, cable drums, boxes, crates, barrels, and so on and so forth. The building industry was weaned from imported roofing and other timbers in the early sixties and now there are three roof-truss manufacturers and one bolted-truss manufacturer producing all the roofing required in the country - all from local structural timber.

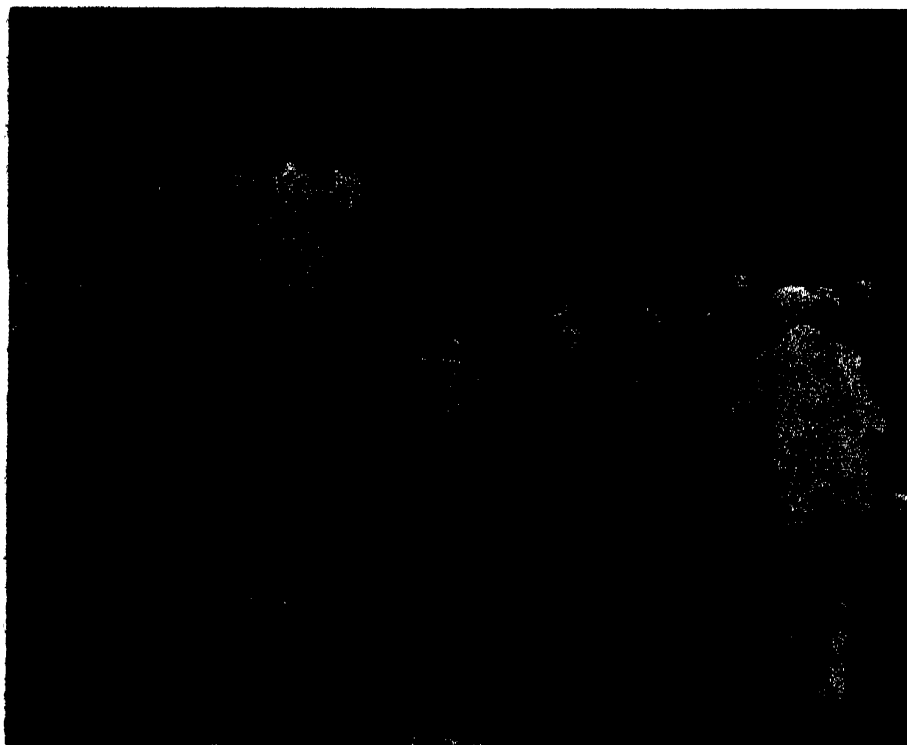
Similarly a furniture industry was established and now the 37 local furniture manufacturing companies are capable of supplying all the country's furniture requirements from the simple cheap ranges to the most expensive and sophisticated suites. In addition, companies have been established which are capable of producing the furniture and fittings required by architects designing buildings for the most exacting clients (such as Sheraton). Our furniture industry has been examined by a UN team who subsequently declared it to be fully capable of producing furniture to meet the needs of countries to the north of us.

Having touched on the history of the timber industry, with particular emphasis on the plantation resources, let me now describe the position in which we find ourselves.

We have 100 000 ha of established plantations with a standing value of about US\$ 70 million. From these we produce annually about 65 000 m³ of structural timber with a sale value of approximately US\$ 18 million, and about 54,000 m³ of case and boxwood with a sale value of approximately US\$ 8 million.

Apart from this we produce in the order of 6 000 m³ of treated transmission poles with a sale value of over US\$ 1.5 million; 2 000 m³ of treated telephone poles with a sale value of over US\$ 750 000; and about 7,000 m³ of treated fencing posts with a sale value of over US\$ 1.25 million. In addition we have an annual production of 30,000 tonnes of pulp and chipboard material for our paper mills and chipboard factories.

Our exports amount to US\$ 600 000 worth of sawn timber, US\$ 500 000 worth of poles and mining timber and US\$ 250 000 worth of processed timber (cable drums, pallets, etcetera). In the furniture market which uses local timber (mainly indigenous hardwood), one sees a fairly impressive export figure of US\$ 5 million.



Charcoal burning. In the foreground, packing of the final product.(Troutbeck Sawmill Ltd.)
(Photo: H. Seppänen)

Our sawmilling capacity is underutilized; and some areas of our plantations are deteriorating because of this. At the same time some manufacturers are importing timber because they cannot obtain the type and specification they require locally, apparently because of the sawmillers' refusal to provide it.



Weighing the sacks of charcoal
(Troutbeck Sawmill Ltd.)
(Photo: H. Seppänen)

Finally - what of the future? I am told that only the advent of a chemical pulp mill will bring greater viability as it will help to promote maximum utilization of our plantation yields.

Progress has been made toward the building of a pulp plant, and tenders are being drafted. However, I believe that we require more than a pulp plant, desirable though that may be.

1. If we were able to obtain the sizes of timber required locally, foreign currency would be saved and more jobs provided.
2. If local authorities responded to a lead by Government to permit the building of timber frame and timber-clad housing, jobs for hundreds of our citizens would be provided in addition to using thousands of cubic metres of timber and providing very suitable housing.

3. The UN team's report on our furniture industry should be implemented, and this could be only with the cooperation of the SADCC countries.
4. If we were able to get the costs of timber down we could export large volumes, probably in a semi-processed condition, to neighbouring countries and possibly overseas.

Our future is bright if the appropriate action is taken by those concerned not least of which is the growers and sawmilling fraternity.

MANAGEMENT AND ORGANIZATIONAL FORMS OF LOGGING OPERATIONS

by

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1. INTRODUCTION

The subject matter of this paper covers a wide variety of items, so many in fact that it will be impossible to discuss them all during this course. We will try to limit ourselves to some of the basics which will assist in making decisions as to how to go and some of what to do when we want to set up a logging enterprise. It is unfortunate that most books written on business forms and organization do not go into logging in their coverage and case examples. As a general rule, however, the basic principles apply to any enterprise. Those wishing to get into the subject in depth must avail themselves of training courses or delve into the innumerable books which have been published.

A logger who wants to start his own business has much to learn and has many options available to him. Not only must he consider the legal implications of his actions but he must also organize and manage in such a manner that the enterprise will perform to his expectations and objectives.

Starting and operating an enterprise is not easy, and anyone wishing to do so must be aware of the problems and hazards which lie ahead. Some are lucky and have business expertise available to them at little or no cost - say, for a governmental enterprise - but at the same time many of these experts know little of the logging industry which is just not like a factory operation.

It stands to reason that for a logging enterprise the potential entrepreneur/appointed party must be knowledgeable, informed and capable, although certain forms of ownership such as sole proprietorship are suitable as a learning process for future expansion to other goals through different forms of ownership.

Before moving on to the first section perhaps we should define what a logging enterprise is. I like to think of it as something which organizes the resources for production and converts them into saleable products.

2. PUBLIC AND PRIVATE ENTERPRISES

The forms of ownership of a business are usually determined by laws which have been enacted by the government of the country. In some countries, however, businesses can be started under common law - not enacted but having the status of law through general usage. These two types are sometimes called corporate and non-corporate companies.

As a first division the forms of ownership may be split into private and public ownership, bearing in mind the fact that forms and legal status will vary from country to country, and must be looked into for each case and country.

In a capitalist or free enterprise system it is generally assumed that an individual or a group of individuals makes the decisions and has the right to start a business to create capital which he/they can invest to generate more capital. Most free enterprise economies no longer have only private enterprises but also public ones and are often called mixed economies.

In this latter case public ownership can be undertaken for many reasons, some of which are:

1. private investors are unwilling to assume the risk;
2. the required investment is too large for private investors;
3. "flagship" and prestige projects are wanted.

In a mixed economy the government has a large say in economic matters but not usually as much as in a collective or socialist system.

Collectivism is basically an economic system which emphasizes strict central control by government over economic decisions. As in the other system some countries allow the other type of enterprise, usually at a controlled level. Present-day economic systems are neither purely capitalistic nor purely communistic, but fall somewhere between.

2.1 Public enterprises

Public enterprises can be wholly or partially owned by government and can be organized in many forms, but the two commonest are corporations and departments. Some are autonomous and some semi-autonomous; one of the commonest differences between public and private enterprises, however, is the control which government can exert, through intervention at various levels and stages of an operation and its management.

State enterprises are frequently set up in the resource (forestry) sector because of state ownership of the forests and the government's desire to utilize the resources for everyone. Some are set up through the need for development and some through nationalization for one reason or another.

Socialized parastatal enterprises probably owe their formation to political action as can be illustrated by the following: in Tanzania the Arusha Declaration of 1967 said: "The way to build socialism is to ensure that the major means of production are under control and ownership of the peasants and the workers themselves through their government and cooperatives." ^{1/}

Many state logging enterprises operate very successfully while others fail to meet their objectives or targets just as in the private sector.

Parastatal operations in a free enterprise economy can probably best be described as playing either a catalytic role or an injector role. In the former the government corporation seeks to establish a permanent non-governmental enterprise by an initial injection of funds. The public investment is then withdrawn and the process repeated elsewhere. In an injector role government capital is more permanently invested.

^{1/} Ghai, Yash: Law in the political economy of public enterprise. African perspectives, Scandinavian Institute of African Studies, Uppsala, Sweden, 1977.

Public companies have advantages and disadvantages, some of which are as follows:

Advantages

1. Easy access to funds;
2. Collection of expertise;
3. First call on the resource;
4. Not always subject to tax;
5. Objective often not primarily financial;
6. Benefit of special regulations, sometimes monopolistic and market protective.

Disadvantages

1. Potential for government interference at all levels;
2. Surplus funds for development lost to central treasury;
3. Control on prices by government;
4. Objectives sometimes not production- and forestry-orientated, to the detriment of the operation and the forests.

Public forms of organization, like private companies, must have a structure, which may be similar to those described under Section 3, Forms of ownership.

2.2 Private enterprises

Private enterprises are those wholly owned by an individual or individuals though for one reason or another some governments may take or have an equity position in an enterprise.

Some reasons for the latter are cases where governments divest or "privatize" a public enterprise and retain an equity or when vital industries get into financial difficulties and are bailed out by the government through taking an equity (share) position.

Most harvesting operations in the so-called free enterprise economies are private but there are cases where they are not, especially in countries whose economies lie somewhere between the two major systems.

Private enterprises are generally under some form of government regulation as to their business practices but also in most countries as regards the procurement of raw materials such as trees which are usually held under the public domain.

Except in some cases where forests are privately owned, operators are heavily dependent on government goodwill and regulations, in addition to the normal practice of good forestry. The allocation systems vary considerably from country to country and in some cases, say, in auctions, a logger may suddenly find himself out of business.

Some advantages of private enterprise are:

1. Unfettered decision-making;
2. Personal involvement and satisfaction;
3. Opportunities for personal financial gain;
4. Legal entity.

Some disadvantages are:

1. Detrimental government regulations;
2. Less certain supply of raw material;
3. Lack of funding;
4. Sometimes double taxation.

There are several forms of ownership or proprietorship which for the most part fall under the aegis of private enterprise, but not always. The jargon or language used to describe these has, at least in most of the world, evolved from the private or free enterprise system.

3. FORMS OF OWNERSHIP

As pointed out earlier, nothing on this subject is concrete, for there are too many political and economic systems in the world for it to be definitive in one place at one time. Things evolve and needs and perceptions change. What works in one country or area or region does not necessarily work in another. The word appropriate is as fitting to this field as it is to the technical one.

In this section some forms of ownership are outlined and although they may not be covered to fit circumstances in a specific country, it is believed that these basics can, with variations, apply almost everywhere, to suit particular situations as dictated by social and environmental considerations and governmental constraints and/or support.

At this point, we should perhaps try to clarify what a business is. A business organization can be said to be an enterprise engaged in production and/or distribution of goods for sale or providing services for a price. Generally the objectives of a business may be to make a profit but there are other objectives which we must remind ourselves of from time to time, such as: the needs of consumers; assistance to government programmes; development of natural resources; provision of employment; and care for the environment. Thus, the objectives of a business, any one of them or collectively, are to produce something. No matter what form this takes, this can be considered as beneficial to someone and may be generally for the good of all through direct participation in its benefits or indirectly through spin-off in economic growth.

3.1 Sole proprietorship

A sole proprietorship is essentially a business (enterprise) owned by one person who is often referred to as an entrepreneur in the truest sense of the word: a person who organizes and manages an enterprise, assuming the risk for profit.

This is probably the earliest form of ownership. Sole proprietorships have grown to be very large but in the process moved to one of the other forms discussed later.

Sole proprietorships usually stem from common law (usage) and there are often no legal requirements in starting them up or terminating them. In some places, say, in a municipality or a city, a permit or licence is required; but this may often not apply to logging operations which are rural based. Sole proprietors may be required to register with and be licensed by the authorities which issue cutting licences/permits, and highway and port authorities whose facilities they may use.

A sole proprietorship is an ideal method of running a logging enterprise when one person can manage the whole operation, even with employees, alone. Some advantages and disadvantages of this form are given below:

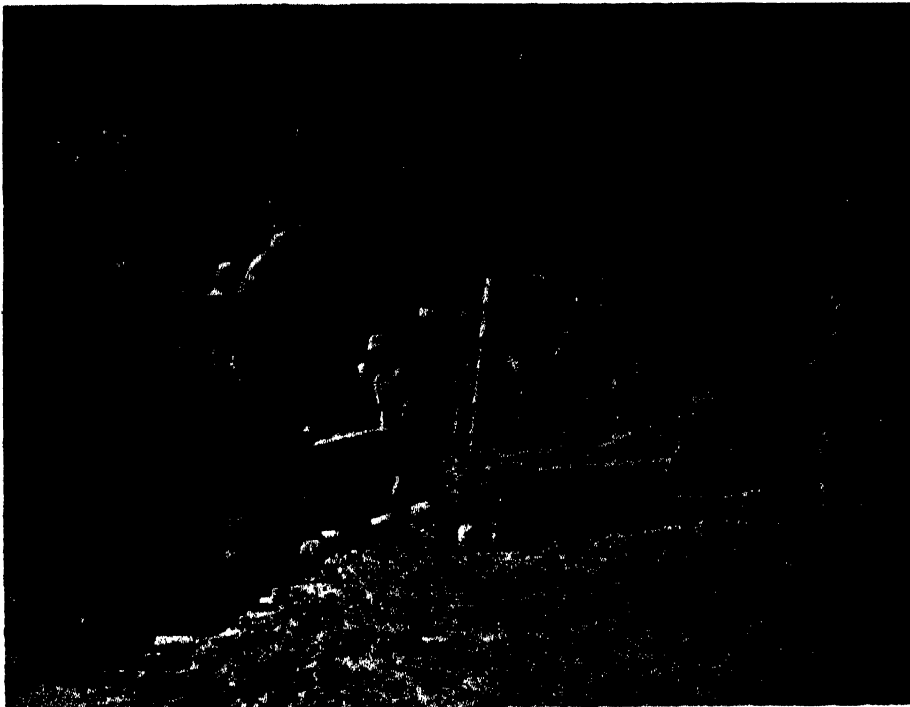
Advantages

1. Strong incentive - everything rests on you, therefore you do your best;
2. Personal satisfaction - you can realize individual potential;
3. Simplicity in starting and stopping;
4. You make your own decisions;
5. Ease of keeping accounts/accountability.

Disadvantages

1. Legal liability for all debts;
2. Difficulty in raising capital;
3. Difficulty in expansion because of the limited capacity of one person;
4. Potential lack of continuity, therefore often difficulties in attracting employees;
5. Lack of chances for forethought (too busy);
6. Entire burden of management.

Sole proprietorships can probably be described in many forms; some which are fairly common in logging are mentioned below.



Manual loading of pulpwood on to 25-ton trailer at the intermediate landing (Mutare Board and Paper Mills) (Photo: H. Seppänen)

3.1.1 Owner/operator (o/o)

This system probably evolved as larger operations became more mature and sophisticated and employee relations became more impersonal, often with reduced productivity accompanied by higher wages and costs.

In order to raise productivity and lower costs a concessionnaire or company agrees to sell a piece or pieces of equipment to the operator(s). The company finances the o/o through deductions on purchase of the logs produced by the o/o, usually through a guaranteed purchase/sales agreement based on a price formula. The company also often holds back certain sums from the purchase price of logs in order to pay for maintenance and repairs of machinery or ensure that they are carried out.

The incentive for the o/o is increased earnings and other advantages listed previously.

The company negotiates log purchase prices which ensure costs lower than before the o/o agreement commenced. Productivity per machine usually increases dramatically, provided the new o/o is experienced and capable. I have heard of one instance where productivity on one machine increased two and a half times.

3.1.2 Piecework

In forest operations this is usually based on volume, therefore misleading. Piecework in some areas is considered a form of exploitation; even in some highly unionized operations, however, it is normal practice.

In felling, where the operator owns his chainsaw and is paid for the volume he fells, this becomes in essence an o/o system. In some areas complicated formulae have been devised which take into account unit volume, tree size, slopes and walking distance to arrive at an acceptable piece rate or contract price.

3.1.3 Trucking

Many logging operations no longer haul their own logs but contract the job out either to one firm (often a sole proprietor) or to o/o's who have or have not purchased their trucks from the company, or have financed their purchase independently of the company.

Whole operations - felling, yarding/skidding, loading, hauling, unloading - can be organized through sole proprietorships, but as the size grows the situation becomes more complex because of logistics and there must be good coordination of all phases and control by the company. Management costs for a company switching to this system may or may not rise because of the need for a different type of supervision, but they should not do so since staff can be diverted to different types of tasks.

3.2 Partnership

A partnership is a form of legal ownership which is essentially an association of two or more persons to carry on a business for profit, although some are happy to earn a standard living being their own bosses. Generally a partnership is not considered to be a legal entity in itself, but one whose ownership is personal and held by partners. Each partner is equally liable. A partnership is more complex than a sole proprietorship.

Although not all countries may have laws governing partnerships some have partnership acts, with varying degrees of control and regulation. Some states require that partnerships be registered with a designated government department and that an annual information return be filed.

Partnerships are often the outgrowth of voluntary association and are often formed in order to overcome some of the disadvantages of a sole proprietorship.

There can be different classes of partners in a partnership, which are agreed on among the partners.

Some classes of partners are as follows:

- (i) General: covers active participants in the business, known to the people doing business with them;
- (ii) Limited: limited partners cannot be called upon to pay the debts of the company; their losses are limited to the amounts they have invested in the business. These partnerships must be formed according to the laws of a state. Sometimes laws require that a partnership have at least one general partner with unlimited liability;
- (iii) Secret: partner is one that the public does not know is connected with the business;
- (iv) Dormant: partner has no share in management functions and the public is not aware of his relationship to the business;
- (v) Senior and junior: some partners may have special powers or authority while others may not. Often the most experienced (and elderly) are made senior partners.

Partnership makes each partner liable for debts, subject to the terms of a limited partnership, and therefore one can be responsible for the actions or inaction of others. Thus it is wise to have an agreement concerning responsibilities, duties, distribution of profits and any other features the association may have agreed upon. Preferably the agreement should be written and legally signed by all parties to avoid future complications. In some partnerships partners take out insurance on the others' lives to cover buying out their interests in the event of death.

A written partnership agreement can be called "the articles of co-partnership" and this does not normally need to be officially approved by any governmental organization. Many people have come to grief and friendships broken up through lack of an agreement which spells everything out. Some items which should be included in an agreement are: date of agreement; names and addresses of partners; type of business; effective period of agreement; name of firm and address; amount of capital invested by each; interest, if any, to be paid on capital; division of profit or loss; salaries of partners; amount of withdrawals permitted; amount of time each must devote to the operation; type of records; outside businesses of partners; duties of each; method of winding up the partnership.

There are advantages and disadvantages in partnership, some of which are relative to other forms of ownership.

Advantages

1. Easy to start;
2. Organization is flexible and informal;
3. No incorporation fees, legal fees are minimal;
4. Greater ability to raise capital;
5. Pooling of talents, complementary abilities;
6. Ease of keeping accounts;
7. Shared responsibility.

Disadvantages

1. Unlimited joint liability (except for limited partners);
2. Partners are taxed personally;
3. Potential for disagreement;
4. Lack of continuity; sometimes business ends with death of a partner.

There are no doubt varied forms of partnerships over the globe which have been formed to carry out many tasks, and partnerships are common in the logging industry. It is here where sharing of talents, complementarity and financial and planning abilities can be put to good use. I have seen excellent logging partnerships between a logger, a mechanic and an accountant/timekeeper, each one of these functions often being considered the mainstay of an operation. Other combinations have been used. Those considering partnerships in logging should perhaps try to ensure that each has different skills to put into the association.

Sometimes a temporary form of partnership called a joint venture may be created for a specific undertaking. Joint ventures can be a partnership of corporations, of partnerships and of sole proprietors. Joint ventures could be useful, say, in logging a windthrown or burned forest where fast action is required and the larger physical capacity can be brought to bear on the problem. Similarly joint ventures can be formed to charter a ship to export logs. In joint ventures it is common for one partner to manage the operation while the other(s) can contribute equipment and expertise, and perhaps carry out certain specific functions.

3.3 Corporation

This heading covers a variety of names which may be used depending on your locale. It is sometimes referred to as a company or a limited company. A corporation can sometimes be distinguished by its title in which the name is followed by such terms as: limited, Ltd., incorporated, Inc.; corporation, Corp.; Oy (Osakeyhtio) for Limited in Finnish; AB (Aktiebolag) for Limited in Swedish, GES.m.b.H., (Gesellschaft mit Baschraenkter Haftung) for Limited Company in Austrian and PLC for Public Limited Company in the U.K.

A corporation is an entity separate and distinct from its owners. In order to incorporate, a charter is required and this is approved by the relevant government department. In essence this act of incorporation by the government confers a separate and distinct entity on the enterprise - separate from its owners. One could say it is a creation of the government. It has been defined as an artificial being, invisible, intangible and existing only by law. Stockholders or shareholders are the real owners of a corporation.

The basic difference between a corporation and sole proprietorships and partnerships is limited liability, that is to say, the owners are not personally liable for debts and obligations unless they have given personal guarantees.

An example from North America can be given to show what is required to incorporate.

In order to become incorporated the founders must prepare and submit to the government (say, the registrar of companies) a certificate of incorporation which must include some basic information as follows: name, purpose, location of principal office, duration of corporation, amount of capital stock, voting rights of shareholders, maximum indebtedness, names and addresses of directors and their powers, names and addresses of incorporators.

If the certificate is accepted, the certificate becomes the article of incorporation or the corporate charter.

Since this charter does not cover many administrative details of the organization, these are included in a set of bylaws. These must adhere to government laws of incorporation and the corporate charter. Some typical provisions are: date and location of annual meetings of shareholders; procedures at meetings; location of principal and other offices; number, powers and term of office and compensation of directors; location and date of meetings of board of directors; designation of officers and how appointed, their duties and terms of office; details regarding capital stock issued such as form of certificates, method of transfer, replacement if lost, method of examination of stock record books by shareholders; corporate seal; procedures for amendment of bylaws.

From the foregoing one can see that the process of incorporation, compared with sole proprietorship and partnership, can be lengthy and costly, since lawyers are heavily involved. It can be said that there must be considerable earnings and overwhelming advantages before one should incorporate.

Companies or corporations are a common form of ownership in the forest industry as a whole, but not always so common for logging operations which stand alone. Often the act of incorporation alone is too heavy for some to handle but there are advantages and disadvantages in incorporation. Some of these are as follows:

Advantages

1. It is a separate and legal entity, apart from its owners;
2. Limited liability;
3. Better chance to raise capital (equity, borrowing), but a small company may have trouble because of 2. above;
4. Permanence (because of 1.);
5. Better opportunity to hire personnel (because of 4.);
6. More varied expertise and management can be hired (size);
7. Ownership is transferable (share sales);
8. Sometimes greater flexibility regarding taxes and succession duties.

Disadvantages

1. Complex and costly to form, must have board of directors and so on;
2. Special taxation regulations, sometimes double taxation and/or higher taxes for personnel;
3. Reports are public.

Under the corporate umbrella some people include such business organizations as: holding companies; close corporations (where shares are closely held); non-profit institutions (hospitals, universities and charitable institutions); government corporations; mutual companies (people supply capital and are clients, as in insurance) and cooperatives. These will not be discussed here but because of the widespread use of cooperatives in many fields they have been included separately, as another form of ownership.

3.4 Cooperatives (co-ops)

A co-op is usually a separate legal entity which may enter into contracts in its corporate name. A co-op is owned collectively by its members who share in its profits and benefits. Co-ops can be said to be incorporated (by government) for the purpose of carrying on a lawful industry or business. Co-ops are generally governed by one department of government working under an act which is often a special one covering cooperatives.

Members of a co-op must own at least one share and normally each member is entitled to one vote regardless of the number of shares held. Return on investment, if the business is successful, is often a fixed percentage. Dividends are paid on a user basis (according to how much a member buys) and this could extend to how much one produces, if it is a logging co-op. Generally membership in a co-op is open to all, subject at times to the classification of the co-op. Normally no member of a co-op is personally liable for debts and other obligations or acts of the co-op except to the amount of shares held. Co-ops are sometimes called societies.

Co-ops are sometimes classified by their terms of association or legal organization, or by their activities such as credit, marketing or production.

The purpose of the association is to facilitate the conduct of business. The best example of a co-op is the purchasing or consumer co-op where members collectively purchase their needs at a lower price due to cooperation and volume. A production co-op, such as one might have in the logging industry, is an association of people capable of producing a product (the log) for sale or for a co-op conversion unit; it would seem that loggers could band together to market logs and other products from the forest (firewood, bark, etc.).

Cooperatives have essentially the same advantages and disadvantages of a corporation but through greater numbers many who otherwise could not would be able to participate and benefit from this form of business.

I do not know of a co-op logging operation in areas where I have worked, but presumably some exist. In 1985 a co-op plywood plant was started on the west coast of Canada, the employees having taken over a mill which had closed because of financial problems. To date I believe they buy their logs from others and it is too early to tell how successful they will be in today's competitive markets with low prices.

3.5 Worker-owned corporation

Another offshoot of a corporation and similar to a co-op is the worker-owned corporation. In this category I know of a plywood mill which has been in operation since 1956. This plant also has its own logging and forestry arms. The worker-owned corporation comes under the companies act in the same way as any corporation, but it has certain built-in advantages. The workers are

shareholders; all have equal rights and are controlled or directed by a plant committee comprised of members from each shift (maintenance, management, shipping) to ensure an equitable cross-section of opinions. There is no union and employees are paid the average rates in the industry in the area.

A share entitles a shareholder to work, but non-shareholders are hired. Surplus earnings, if any, are distributed as dividends to shareholders. The main advantages of this form of ownership are continuity of employment and flexibility, which in times of adverse markets enable them to survive when others go under.

One often successful variation of this is worker partnership (ownership) whereby the owner lets employees buy shares through payroll deductions, delineating a specific amount of control which they may eventually buy.

As repeated throughout this paper it must be remembered that forms and conditions of ownership can, do or will vary from country to country and even within a country. The onus is on the potential entrepreneur or incorporators to apprise themselves of the situation vis-à-vis laws, rules and regulations for the area in which they wish to operate. A potential exporter must also know the rules of the countries to which he wishes to export, for he may need to form a subsidiary in another country, or be better off doing so.

4. ORGANIZING AN ENTERPRISE

Not everyone has the capability or bent to start a business which will begin and continue on a sound footing. Just as it is essential to pick the right form to suit one's, or a group's, temperament and objectives, it is necessary that a person evaluate himself prior to making any moves.

Self-evaluation is one of the most difficult things to do. People seem either to get confused or to tend toward overestimating their capabilities. One must realize and understand why one wants to be in business. A thing to remember is that the people who are most successful at it are those who like doing what they do in the business. Some of the most common causes of failures have been given as the following:

1. Lack of personal qualifications to run a business;
2. Lack of experience in the line of business;
3. Lack of training and experience as a manager;
4. Unbalanced experience. 1/

It would seem that no logger would normally flounder because of No. 2 above, but many would through items 1 and 3. As a working logger becomes an owner/manager the scope of his expertise and knowledge must expand greatly in order to meet the new demands of managing a business. If he does not know how to manage, and is not aware of trends in the industry, he may soon find himself at the mercy of the industries which use his logs or the brokers who buy them for export.

1/ Dun and Bradstreet annual report on Canada for small businesses quoted in the Independent Business Handbook.

Some success characteristics are: drive, ability to think (original, creative, analytical), curiosity, good human relations, communications ability, technical knowledge. One should try to assess whether one has these qualifications and see whether in the proposed business venture one will need them all. Obviously a person must have ambition or he would not be looking into the possibility of starting a business venture. He must not be a dreamer - he must act.

The establishment of a successful corporation does not rely solely on the merits of one or two men and for this reason confers an advantage since it is usually larger than sole proprietorships and partnerships and can hire the expertise required. The basic requirements for starting a business are feasibility (which expertise can be hired to determine) and choice of the type of organization which will perform best.

4.1 Structures of organization

For single proprietorship and partnership businesses the organization is relatively simple. The sole proprietor does it his way and if he has help he simply tells them what to do and monitors and controls their activities. One could call this the original line-organization of which more will be said later.

The organization of a partnership is more complex, but can be started by a memorandum of agreement which should specify the duties and responsibilities of each partner. If there happens to be a senior partner management could in effect be by direct line organization. Partnerships often fail through disagreements which have arisen because of a lack of some form of organization or clear authority relationships.

The organization of a corporation is much more complex than the other two forms because of size and interrelationships which are brought into play in an attempt to run the business effectively. Organization has to do with order; order prevents chaos. People organize or are organized because they can achieve more by working together rather than alone.

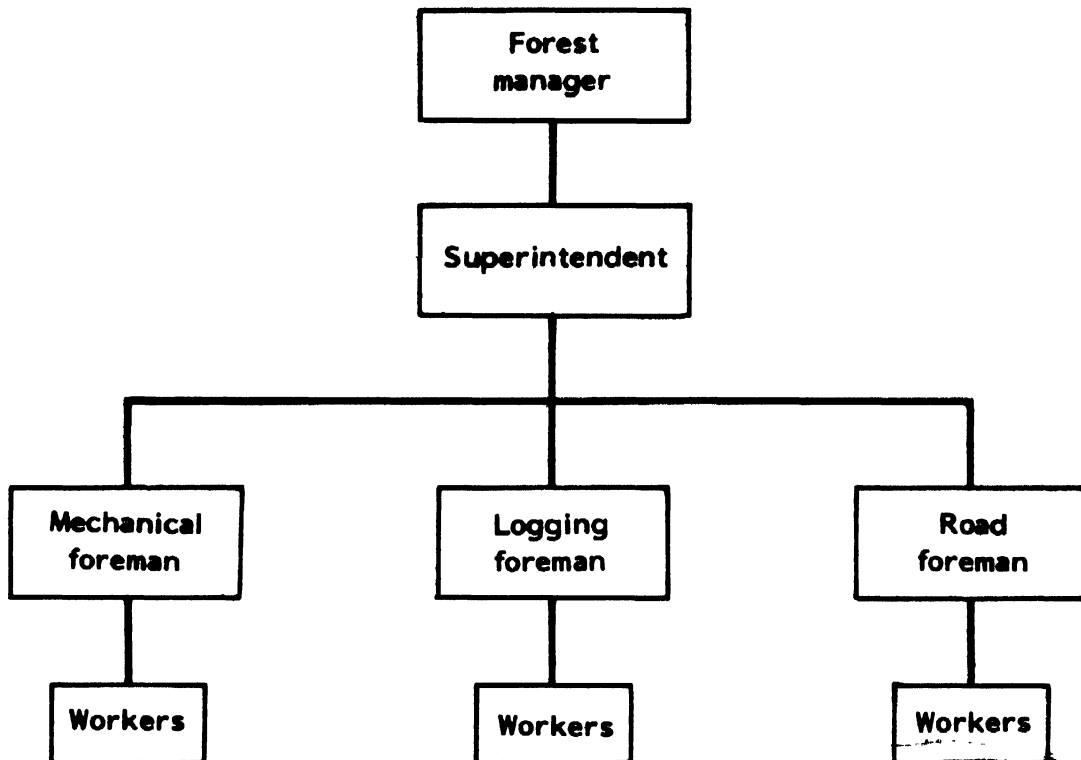
There are basically two forms of structure in use today, the line and line-staff. A third more complex form called matrix has, however, also been used.

It should be noted that structures do not simply happen or come out of a book. They evolve and there are variations on basic structures. Nomenclature may differ from one area to another, but the basic structures can be made to fit most needs.

4.1.1 Line organization

A line organization is a form in which there is a line of authority from the top down to the operating employee. This authority is direct, but it is usually passed along through one or more managerial/supervisory levels. An example is the superintendent who controls the actual operation and passes orders from management to the foremen who in turn pass them to the workers. A line organization is often referred to as a military type of organization.

A typical line chart for a logging operation might be as shown below, although it could be simpler or more complex.



Some of the advantages and disadvantages of a line structure are as follows:

Advantages

1. Simple, easy to understand;
2. Easy to see what each should do, and if he is doing it;
3. Control is simple;
4. Decisions can be made quickly;
5. Relationships are understood, which prevents or lessens conflict and criticism, if orders are carried out.

Disadvantages

1. Supervisors (foremen) need to be knowledgeable in more than one field (and they cannot always be);
2. Lack of specialization;
3. Top management is too involved - cannot take time to think, plan and make policy.

When it is difficult to find foremen/supervisors who know all the jobs at the work level, responsibilities based on the different functions to be performed can be spread among several foremen. This is sometimes called a functional organization. In this form, the workers may sometimes be required to take orders from more than one foreman, but only with regard to the particular function over which each foreman has control. This can sometimes create difficulties. An example might be fellers under a felling foreman who must fell right of way under a road foreman. Another potential conflict is with machine operators who are supposed to run their machines according to the mechanical foreman's instructions. So even a basic line-organization structure can produce problems - but this is where line-authority from management must play its role.

4.1.2 Line-staff organization

In a growth situation the need for specialized staff can become acute. The line and staff organization developed in order to try to eliminate the need for managers/supervisors to be highly competent in all phases of their work. Essentially, separate staff departments and technical specialists and staff to assist executives are added to a basic line organization.

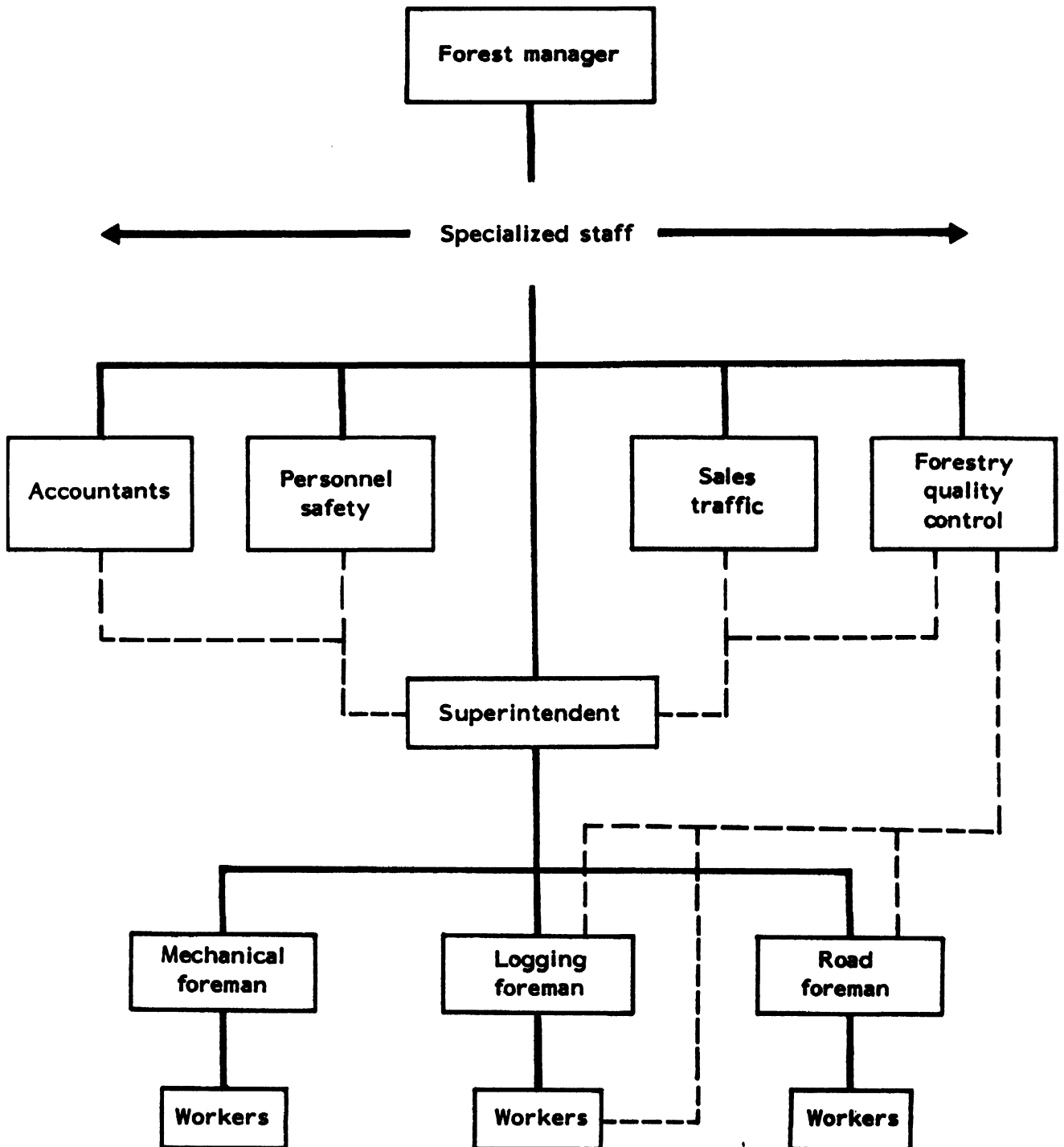
When separate staff departments are added, the specialists study and make recommendations on problems assigned to them or which may arise. They may develop plans and work procedures which assist the operating (line) departments.

The head of a separate staff department has line control only over the people in his department. Conflicts can arise between line and staff executives (supervisors) unless the lines of authority are clear-cut and well defined, and cooperative relationships exist. The manager must not allow competitiveness to develop between line and staff personnel. Staff assistants do not normally make decisions but only help executives in a particular field.

It would seem that line-staff organization is best suited to an integrated complex where logging is one portion of the whole, but large logging companies can also be organized in this manner. A chart showing flow/advice lines from staff to line is given below as an example.

It should be noted that the flow of advice need not necessarily be through the superintendent. Provided management has a clear picture of what is going on and has good authoritative control, it can and does allow direct communication. It should also be noted that most large logging operations are not formal. Often the forestry crews talk directly to the fellers and road constructors, just as accountants/timekeepers talk to each and every one as the situation dictates. What is important is that everyone realize where the final responsibility and thus authority lies. A major failure in authority relationships occurs where a manager/supervisor who does not know his job, or is incompetent, takes advice (sometimes bad) from someone he believes to be knowledgeable where he, the manager, is not, and allows control to slip away to the adviser. The latter may have goals of his own which are not those of the company.

An expanded line organization is probably the norm in most large logging companies. The situation becomes logistically complex if a company has more than one operation, each usually far distant from the other. This then becomes a problem of delegation of authority versus tight central control, and different profit centres. We will not delve into the complexities of this form but suffice it to say that physical dispersion and centralized management enter into the



—— line flow
- - - - advice

management equation. The structure would normally be a largely expanded line or line-staff structure but could have three levels of authority, or two, in which case the senior manager would have many more managers reporting to him than in the three-tiered structure.

Many logging operations work successfully without organizational charts and formal spelling-out of duties but this comes about through common usage, and some formality may be a good thing for new companies, especially in areas where there is no experience or expertise in operational management. Charts sometimes disclose defects in the assignment of duties and responsibilities.

Some advantages and disadvantages of this structure are given below.

Advantages

1. Adds specialized knowledge;
2. Reduces load on manager;
3. Retains authority/responsibility of a line structure.

Disadvantages

1. There is potential for conflicts when advice is perceived as an order or demand, leading to friction with associated problems;
2. There is potential for power-grabbing and bad advice;
3. Manager tends to become more remote and loses touch.

4.1.3 Matrix or project organization

A matrix organization is said to have come about from the need to cut across departmental lines to accomplish special tasks. Basically it tries to coordinate functional departments and is prevalent in, say, development by a consulting firm of a project for some large undertaking such as a pulp mill. It is rather doubtful that the system really applies to logging which already has its departments by function.

In a matrix or project organization one person is usually designated as project manager and has call upon staff/employees from within the traditional line or pyramidal form of organization. Normally the project manager also has outside relationships with subcontractors, suppliers and so on.

Project or matrix organization can be complex and, it has been said, should be applied only to highly important jobs which require the special coordination of several specialties. It does not appear that this form would add much to a logging operation.

4.2 Coordination

Large operations involve task specialization and the operating and managerial work of the company must be differentiated to determine which department or person will be responsible for special activities. This can be referred to as coordination, which can be subdivided into horizontal and vertical. Both are necessary.

Vertical coordination relates to the managerial side. Established lines of communication are followed and a manager/supervisor does not bypass subordinates by giving orders to a lower level. Similarly, questions requiring decisions are passed up the line without bypassing.

Horizontal coordination relates to the operating side and means that persons at each level of a department work together effectively. This coordination is in part achieved by allowing communication to take place laterally rather than vertically through the supervisor/ manager and back down again, which is time-consuming and less effective than direct communication. The task of the supervisor is to intervene and make decisions when problems on procedure cannot be worked out by the personnel involved. The supervisor must know that internal talks are going on and what they are about. A logging operation is normally informal and horizontal coordination is common.

5. FUNCTIONS OF MANAGEMENT

Forming and organizing an organization are the basic tasks required of managers and must be considered as the groundwork for the job to be done; for an organization is not an end in itself but should function to achieve a goal. The job of management in any organization is to coordinate and organize efforts of the people in a company so that they fulfill the tasks and goals for which they were employed. Management must also combine the resources available to it (people, money, machines, raw materials) into an entity that turns out a product which is saleable and competitively priced. Management has to lead, to be innovative and to be farseeing.

Large companies or logging operations usually have three levels of management: top (forest manager), middle (superintendent), and operations (foremen). When a company is a subsidiary or operating arm of a large integrated company, however, the categories could change to: top (vice-president woodlands), middle (manager, superintendent), operations (foremen).

The basic functions of management are described below.

5.1 Policy and planning

In thinking through what it is hoped to accomplish, a manager must evaluate various possibilities and decide on a course of action. Planning requires analytical ability, imagination and some forecasting. Through the policy and planning process the overall objectives of the enterprise must be established.

5.2 Direction

Success in getting things done depends to a considerable degree upon management's ability to give leadership.

Leadership is the ability to persuade others to carry out tasks to the best of their ability, recognizing that it is a two-way process in which the leader influences others but is also responsive to their desires.

There are basically three styles of leadership: authoritarian (makes decisions without consulting); participative, often referred to as democratic (invites participation of others in decision-making); non-interfering (leaves decisions to others by giving them a free hand). Another way of regarding management styles may be to see them as hands-on or hands-off management.

There can be problems in any or all of these, but most operations I have seen tend to be authoritarian with some democracy at the higher levels. Some inexperienced managers (technical, managerial) incline toward non-interference which can have serious consequences.

5.3 Staff selection

This is a critical function of management. The choice of qualified staff, from foreman to manager or vice-president, is important and especially so in the selection of people with potential leadership and management abilities. Even if these are latent they can be brought out or developed. Promotion systems must be developed so that opportunities can be seen by those with abilities and ambition.

5.4 Control

Control is a means by which management can ensure that the operation is measuring up to its goals. Managers must be prepared to give responsibility to subordinates so that they have the will to do a good job and the managers themselves are freed for planning, directing and coordinating. In so doing, however, they must have a way to ensure that on all levels the operation is performing as expected.

In order to control, it is usually necessary to have or establish standards of comparison. In logging, productivity per machine is a standard most experienced loggers know; but probably the best is cost control which is linked to productivity.

Quality control is relatively easy in a woods operation since the product is a log for which, in most countries, there are grading rules for local use and for export. Apart from these, there is an opportunity, which many miss, to control quality through their scaling and grading units and a feedback to the felling crews.

5.5 Information

If people are to carry out tasks required to meet goals, they must be informed. It is the responsibility of management to see that people understand what the operation is trying to do (for example, export high-quality logs) and where it is trying to go (for example, capture a larger share of a market, expand).

Information apart from basic operational details, production quotas, etcetera, can be passed along by indoctrination courses, training, training manuals, films, video and so on.

5.6 Representation

The manager must represent the company/operation to outside people, organizations, government and trade unions. At times this task calls for subtlety and diplomacy while at others it demands forthrightness and forcefulness.

6. INTERRELATIONSHIPS IN AN ENTERPRISE

A logging operation does not always conform to standard textbook organizational structures, nor follow classic managerial principles. As said earlier, most are authoritarian to democratic with a strong hands-on approach.

Most forest managers have come up through the rough forest environment which requires not only skills but stamina and staying power. A good forest manager knows through experience how much his men can handle and tolerate. He is therefore often more easygoing as far as interrelationships between himself and his personnel and among departments are concerned. He normally has good control backed by unquestionable authority, therefore he can tolerate interdepartmental dialogue and cross-fertilization of ideas.

A manager is expected to have an understanding of who should do what. He organizes his management team around this knowledge. Relationships in the enterprise will normally be established on the basis of the structure that has been chosen (line, etc.). This, however, implies a formality which does not always characterize an enterprise, especially a private one.

In a logging operation there is basically the operating side which physically produces logs, supported by various departments or functional sections without which the operation could not long survive unless it is small and has a many-talented crew.

These support or non-producing departments are generally mechanical, accounting, personnel and sometimes road building and forest engineering. Each of them is normally headed by a foreman or chief. These leaders essentially make up the so-called management team.

For instance, when planning, policy and strategy are being discussed or altered, the manager would ordinarily rely on his forestry, accounts and operational (superintendent) chiefs to advise and provide substantial inputs. When planning productivity and annual cut, he would rely for basic plans on his engineering section with productivity inputs from the superintendent who has consulted the respective foremen. In potential labour negotiations he would rely heavily on the chief of personnel, with accounts and the superintendent giving major inputs of basic information needed for the approach strategy.

At a lower level such as in everyday operational procedures each department knows that its reason for being is to produce logs. Non-producing sections must gear their activities to assistance and back-up.

A logging foreman, for example, holds discussions with the mechanical foreman as to when a machine which has been delivered and whose problem has been discussed with the shop personnel by the operator will be ready to go back on line. He relays this information to the superintendent who alters work schedules and daily production plans accordingly.

A logging foreman turns in daily time/production sheets and discusses any oddities or production and staff problems with the time-keeper who passes information of immediate concern to the relevant party.

The forestry staff know the quality and size requirements for logs and impart this to the head of felling and sometimes his fellers. They monitor the scaler/graders and therefore to some degree have a form of control over the entire felling/scaling department. Similarly they will check output (unit volume removed) against their estimates of volumes available in the standing forest, thus to a degree controlling the removal crews.

As will be seen, the relationships are numerous and the fact that they are informal helps to make things function. A rigid vertically coordinated communication up and down the ladder would probably not work in such a fluid

environment as the forest. This is not to say that some formality must not be incorporated. Meetings, informal or formal, are a good way to find out, and to inform. Unfortunately, many loggers do not care for formal meetings, therefore a hands-on supervisor must meet and discuss with his men at every opportunity during the working period.

A good management tool, in the uneven work schedules of the forest, is daily gatherings/meetings of senior personnel at the end of each day so that supervisors know what has happened and what plans must be changed, and can contribute to finding solutions. Similarly, meetings of a few key personnel before the workers leave for the woods in the morning can clear up problems which arose overnight.

No doubt relationships will not always be easy. Power struggles develop which are not always clear and clean. The head forest engineer may answer to a chief engineer at head office as may an accountant who is outposted. These latter can be used to bring pressures on a manager.

The question has often arisen of whether or not the engineering section comes under operations or the manager. As a forest manager, I used the engineering section as a planning and control mechanism and kept them under me for the simple reason that the production staff can do their own work (while the manager cannot always be there) in order to raise production, and lose sight of some other objective such as regeneration or protection against fire. This can cause friction between operating and engineering forestry personnel.

For an operation to be effective, there must be interaction and the informality normally found in logging operations allows the whole to grow and above all to adapt to changing situations (terrain, markets). Professional loggers normally have a sense of belonging and pride in their capabilities. It is one of the tasks of management to ensure that this sense is maintained or instilled and some informality and hands-on management is often the way to do it.

REFERENCES

- Ashley, C.A. & Smalls, R.G.H.: Canadian Crown Corporations, MacMillan Co. of
1965 Canada, Toronto.
- Dale, Ernest: Organization, American Management Association, N.Y., N.Y.
1967
- Fitzgerald, P.A., Chamard, J.C. et al: Business - its nature and environment,
1979 Sage Publishing Limited, Toronto (1st Canadian edition).
- Gentry, D.L. & Taff, C.A.: Elements of business enterprise, Ronald Press
1966 N.Y., N.Y. (2nd edition).
- Ghai, Yash: Law in the political economy of public enterprises - African
1977 perspectives, Scandinavian Institute of African Studies, Uppsala,
Sweden.
- Owens, Richard N.: Management of industrial enterprises, Richard D. Irwin Inc.,
1965 Homewood, Ill. USA.
- Province of British Columbia: Independent business handbook, Ministry of
1983 Industry and Small Business Development, Victoria, B.C., Canada.
- Reinecke, J.A. & Schoelz, W.F.: Introduction to business, Azzyn & Bacon, Boston,
1974 USA.

OPERATIONAL PLANNING OF FOREST WORK

by

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1. INTRODUCTION: PLANNING IN FORESTRY

The saying "properly planned is half done" is applicable to all the work in forestry.

The first phase and thus the basis for all planning is the planning of the strategy for an organization. Strategic plans must answer the questions, what must be done and why must it be done?

Operational plans are made to attain the specified goals, so they are always based on the strategic plans. They answer the questions, how and when must operations be carried out, and who must carry them out?

Plans can also be categorized according to their time span; as in long-term planning (5 years or more before the operation), medium-term planning (2-5 years before the operation) and short-term planning (1-2 years before the operation). The nearer in time the actual operation is, the more detailed the plan must be.

Plans must also be flexible; it must be possible to change them if the need arises. On the other hand, proper plans are not just drafts; it is a sign of poor or incompetent planning if finished plans are changed too often.

More detailed planning is necessary when the time for the actual operation is approaching. This is usually carried out by the personnel in charge of the operation; in the planning of logging operations, by forest officers and logging supervisors. At this stage the questions of how, when and who must be answered satisfactorily in every particular.

2. PLANNING OF LOGGING IN FINNISH STATE FORESTS

An example of logging planning in natural forests with a long rotation age (80-120 years) is the system used in the Finnish state forests:

<u>Type of activity</u>	<u>Years before felling</u>
Location of cutting area	4 +
Marking of boundaries	3 (or 2)
Felling plan	3 (or 2)
<u>Operational plan</u>	2
Marketing plan	1
Work plan	less than 1

The operational plan which, it will be observed, must be completed two years before the planned felling year, encompasses all the following functions:

1. Division of the logging area into settings
2. Planning of branch roads and landings
3. Marking
4. Measuring (standing trees)
5. Division into work units (strips) and classifications
6. Selection of logging method(s)
7. Cost calculations.

A finished plan contains the following elements:

- (a) Logging area maps
 - boundaries of the area, settings and strips
 - terrain transport directions
 - road and landings
 - special conditions affecting the operation.
- (b) Measuring results (compartment sheets)
 - quantities
 - types of timber
 - felling work classifications
 - terrain transport classifications and distances
 - felling and terrain transport costs for strips, settings and the whole area.
- (c) Cost calculations
 - alternative felling and terrain transport methods
 - alternative transport methods and delivery points.
- (d) Markings in the logging area
 - area, setting and strip boundaries
 - strip roads and landings.

All logging plans for a forest district are combined in an annual district logging plan.

According to the alternative cost calculations the headquarters marketing office sells the wood and informs the district about the specifications for timber types, delivery points and transport time schedules.

3. PLANNING LOGGING IN FAST-GROWING PLANTATION FORESTS

The following example is of logging in manmade plantation forests with a short rotation age (10-24 years) and relatively small areas and quantities. This system has been used in industrial plantations of Zambia. The plan is based on the compartment register and partly also on the needs of the industry. The whole plan consists of:

- a marketing plan
- a production plan (own industry)
- a felling plan
- an operational plan.

The plans are completed one year before the actual operation. The operational plan includes the following details:

- time of year when transport is possible
- survey records (quantities, types of timber)
- logging method, landings
- delivery points
- road maintenance plan
- manpower and machinery needs
- cost calculations.

4. PLANNING IMPLEMENTATION OF A LOGGING OPERATION

Well in advance of the start of a new logging operation, a logging officer or supervisor must check the finished plans which are usually at least a year old at this stage. It is the supervisor's responsibility to ensure that everything is ready before he moves his crew to the new site. By this time the questions of when and who must be completely and satisfactorily answered. The following items must be checked:

- (a) Documents
 - logging plan, maps.
- (b) Road conditions
 - maintenance needs
 - bridges, culverts
 - traffic signs.
- (c) Boundaries
- (d) New constructions
 - branch roads
 - landings
 - skidding tracks
 - yarder stations.
- (e) Manpower (for felling)
 - quantity, quality
 - tools, maintenance of tools
 - transport of workers
 - water, food
 - rest huts, shelters, camp sites
 - protective clothes
 - first aid.
- (f) Machinery (and animals)
 - quantity, quality
 - operators, number of shifts
 - service, maintenance, repair
 - fuel, lubricants, water.
- (g) Landings, loading, transport
 - transport plan
 - measuring
 - delivery.

- (h) Supervision
 - supervisors, responsibilities
 - communications.
- (i) Starting
 - time
 - place, point
 - starting information.

5. STARTING INFORMATION

Before starting work in a new logging area the supervisor should inform his men about conditions there. The following information should be given to them:

- basic facts about the logging area (size, boundaries, settings, shifts, working schedule, etc.)
- felling method, timber types (new instructions)
- tools, maintenance of tools
- safety regulations
- supervision
- working time
- transport of workers
- pay system
- communications
- location of rest shelters, water drums
- first aid
- other activities in the area.

6. PLANNING DURING THE OPERATION

To keep all the work under control and to know at all times the actual situation and progress of the logging operation, the supervisor must use method in managing it. In logging especially, conditions may change quickly and if/when this happens, plans must also be speedily revised or even changed to avoid financial losses. A logging supervisor should have the following "tools" for adjusting plans quickly:

- (a) Map or maps for
 - felling
 - roads
 - transport
 - operations.
- (b) Standards for
 - production (men, machines)
 - cost.
- (c) Records
 - daily, weekly, monthly.
- (d) Graphs
 - logging operation schedule
 - output (felling, extraction, transport)
 - target/production
 - costs, etc.
- (e) Service schedule for machines.

Short-term planning is needed in unexpected situations such as the following:

- changes in wood demand
- changes in logging and transport output
- outbreaks of fire, insects, etc.

Flexibility in the timing of felling, terrain transport, loading and transport can be secured by using or adapting the following:

- spare "emergency" compartments
- felling methods (clearfelling/thinning, chainsaw/bowsaw)
- skidding distances
- transport distances
- alternative loading and offloading methods.



In thinnings of Pinus patula forests the logs were skidded in tree lengths to the landing where they were bucked with a bowsaw or light chainsaw and stacked manually (Border Timbers Ltd.) (Photo: H. Seppänen)

7. PLANNING FOREST ROAD MAINTENANCE

Before any major transport operation, the road(s) must be checked and all parties with an interest (the road owner, the user, the constructor) should agree upon a maintenance plan. This plan should include:

- what must be done before the operation
- what must be done during the operation
- what must be done after the operation
- who should do what (organizations, responsibilities)
- how the costs should be divided.

The road should always be checked after a logging operation and also after maintenance.

8. SUPERVISION OF LOGGING WORK

The supervision of logging operations includes both general supervision and systematic checking. To get a complete view of each phase of the operation the supervisor should make use of a checklist. In felling, for example, the checklist should include:

- directional felling
- felling techniques
- height of stump
- debranching, (debarking)
- crosscutting into different types
- piling
- tools
- safety
- working time
- fire protection
- clearing of roads and firebreaks
- rest shelters, water drums, etc.

Similar checklists should be made for other logging operations and locations like terrain transport, landings, terminal transport and roads.

9. CONCLUSIONS

The importance of planning in all forestry operations and work cannot be too strongly emphasized. Cooperation between planning and implementation must be close when the organizations or people in charge of the operation are not those who planned it. Planning is never a separate activity or a value in itself. The sole purpose of an operational plan is to make the implementation of a forestry operation practical, easy and economic. A good plan must be revisable if the need arises and it must also include alternative solutions for at least the risky parts of the operation.

PLANNING THE WOOD SUPPLY FOR FOREST INDUSTRIES

by

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1. INTRODUCTION

One of the greatest dangers in initiating a wood-based enterprise is to assume that wood supply is a simple process which will more or less look after itself. In both the developing and the developed world many forest industrial enterprises have either failed or have suffered heavy losses because this assumption has been made. Wood supply is seldom, if ever, such a simple process. Instead it is one which requires well laid plans, trained workers, skilled managers and ample funding if an adequate, sustained wood supply is to be ensured at a reasonable cost. Without an adequate, sustained wood supply, the conversion plant will not operate at predicted levels and the benefits expected from its establishment will not be realized.

2. FOREST CONSIDERATIONS IN PLANNING THE CONVERSION PLANT

The volume of suitable wood which can be made available and the cost at which it can be produced are major constraints on the development of any forest enterprise. A substantial source of information on the potential wood supply - volume, species, dimension and use characteristics - and accurately estimated costs of delivery to potential mill sites, must be available to the mill planner at a very early stage of the project.

The cost of wood frequently amounts to 50 percent or more of the total operating cost of a conversion plant. Transportation, in turn, forms a substantial portion of the wood cost. Consequently, when the site of a conversion plant is determined, due consideration must be given to location in relation to wood supply sources and to facilities for wood transportation. Where there are several site options, wood transportation cost may well be the decisive factor in making the site selection.

For harvesting, a transportation network must be developed throughout the forest. In most cases the cost of this network must be amortized against the volume of wood harvested. Any restriction on the volume which can be harvested per unit of forest area will result in a higher cost of wood. For example, road amortization per cubic metre of wood will be about 10 times as high if the harvest is 10 m³ per hectare as it would be if the harvest were 100 m³ per hectare in the same forest.

The nature of the projected conversion plant can restrict the potential harvest. A veneer mill or plywood plant is more selective in its wood requirements, a sawmill somewhat less so, and a pulp mill or particleboard plant least of all. A veneer mill operating alone, then, must expect substantially higher wood costs than one operating in conjunction with a sawmill or a group of sawmills. In the same way, a sawmill operating with a pulp mill or a pulp mill

operating with a group of sawmills is likely to achieve lower wood costs and higher value from the forest than any single-product unit. Whenever forests are suitable and markets are available, industrial development should be planned to use as wide a range of tree sizes and log qualities as possible.



A pair of oxen used in Pinus patula thinnings.
The average daily production was 10 m³ per pair
and the average skidding distance 30 m
(Border Timbers Ltd.) (Photo: H. Seppänen)

In all cases, the planner of a forest enterprise must carefully consider the location and characteristics of the forest resource as well as the market opportunities, technical processes and social needs before reaching a decision on nature, location and productive capacity of a projected conversion plant. Once the decisions have been reached, a log specification describing the type or types of wood should be prepared and a budget showing the volumes which will be required each month should be compiled. This specification and this budget then become the targets for the wood supply organization.

Forest considerations not only affect the general nature of the conversion plant but also enter into the detailed design. The characteristics of the wood supply, the method of logging and wood transportation, and the length of the harvesting season must be carefully considered in all wood-handling functions at the plant. For example, the design for a sawmill based on a forest of small softwood trees will be significantly different from that of one based on a forest of large tropical hardwoods.

Somewhat less obvious but perhaps equally important are the different requirements in handling waste if the log supply is sound or defective or the differences in dry kiln requirements for species with varying drying schedules. These and other variations in wood characteristics must be fully reflected in detailed plant design.

Mill wood-handling installations must be fully compatible with planned logging systems. Both should be selected to obtain the best possible combination from an overall viewpoint, not from a single viewpoint of either milling or harvesting. It is vitally important that sufficient storage area is provided to permit mill operation throughout the year even though harvesting and log transport may not be possible in all seasons.

3. CONSIDERATIONS IN PLANNING WOOD SUPPLY

3.1 The forest

Basic to any plan for a forest industries enterprise is a thorough knowledge of the forest in the wood supply area. A first requirement is a knowledge of the characteristics of the species which make up the forest and the effects which these characteristics have on the use to which the wood will be put, the manner in which it must be handled, and the markets in which it may be sold. Examples of such characteristics include shape, form, density, durability, colour and figure, mechanical properties and chemical or mineral additives within the wood. Most of these data are readily available for species in common use but original research may be required for species which have not been exploited in the past.

Specific data on the forest itself are also vital. They include:

- total volume by species and by forest type;
- volume per unit area by species in each forest type;
- the diameter class distribution of the mature trees in each species or group;
- the age class distribution of the trees in the forest;
- the incidence of rot or other defects in each species;
- the volume that is suitable for high-value products.

In most forest regions some inventories have been carried out but not all will have sufficient accurate data for project planning. In many cases, a new inventory must be the first stage of project planning.

Many forests throughout the world are either now under management for sustained yield or will come under management as soon as it becomes practicable. The management plan limits the annual harvest to the allowable annual cut and frequently designates a cutting cycle. Both these restrictions are most important in planning wood supply. In addition, silviculture considerations may call for partial cutting so that the actual harvest per unit area may be only a fraction of the potential indicated by the inventory data.

When all the required forest data have been obtained and analysed, the following preliminary estimates can be developed:

- the volume of suitable wood which can be harvested each year;
- the potential production per unit area;
- the forest area which must be harvested for a given level of production;
- the roads or other transport facilities which must be built each year to develop the required production.



Logs loaded on to trucks by a hydraulic crane attached behind the cabin. With appropriate positioning two trucks could be loaded by one crane (Border Timbers Ltd.) (Photo: H. Seppänen)

3.2 Terrain and topography

Terrain and topography enter into wood supply planning in a large number of ways.

First, they may bring about a reduction in the allowable or practicable harvest. In steep mountainous areas some forests may be designated as protection forests in which no harvesting can take place and others may be so steep and rough that harvesting is not practicable.

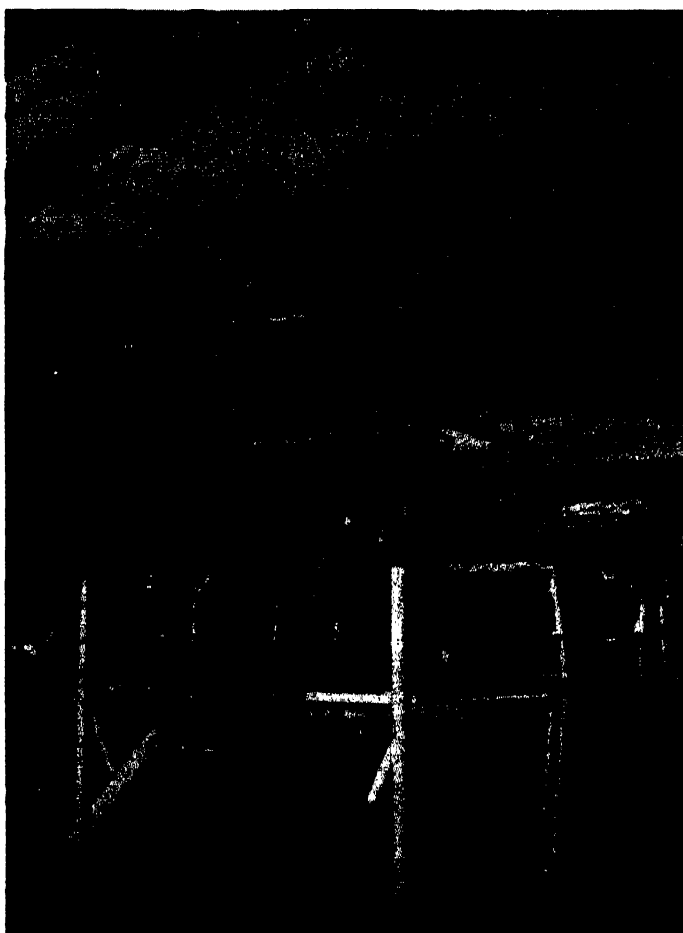
Second, terrain and topography affect the selection of the logging systems and these in turn affect the delivered cost of wood.

Third, roughness of the terrain can affect the productivity of the selected logging system. For any degree of slope, harvesting is easiest on even ground and most difficult on very rough or broken ground.

Fourth, terrain and topography will affect both the method and cost of road construction and may affect the amount of wood required. Road construction will be difficult and costly both in steep, rocky terrain and in swampy areas where the soil moisture content is high. More roads must be built where there are protection forests and areas impracticable to log as such areas must be traversed to reach the forests beyond.

Fifth, rivers and waterways may be impediments to logging or they may provide avenues for log transportation. The need for bridges can greatly increase the cost of the transportation network.

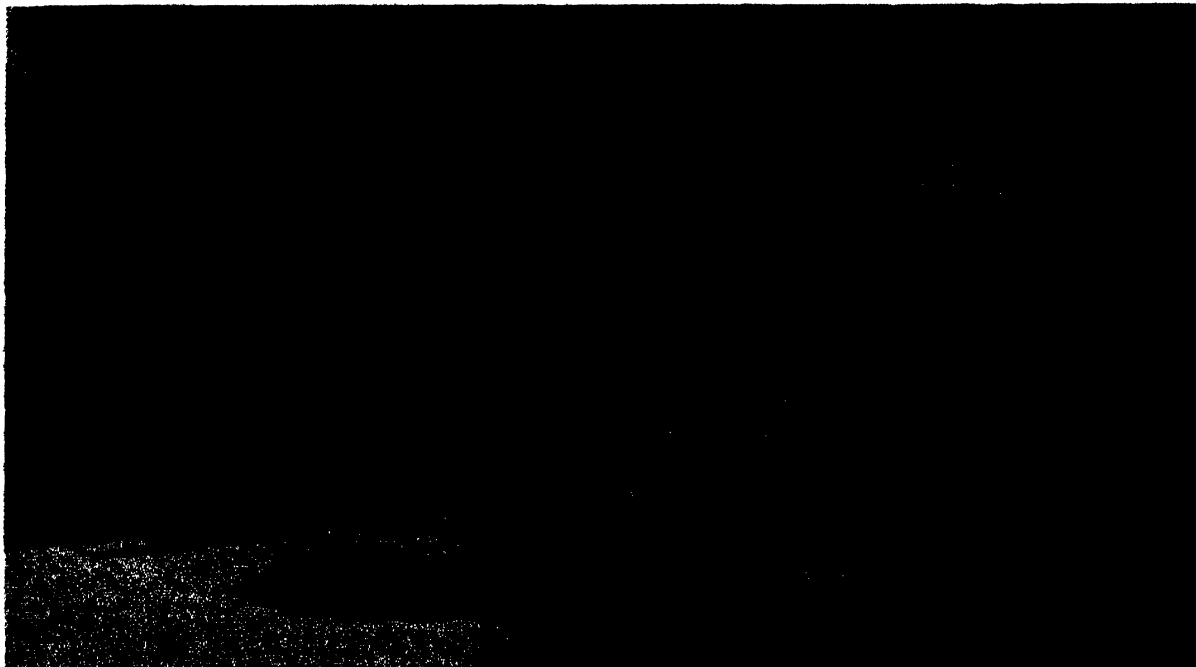
Forest planners must have a thorough knowledge of the terrain in which harvesting is to take place. The best sources are aerial photographs or topographical maps which also show afforested areas and timber types, but even these sources should be supplemented by reconnaissance surveys carried out by experienced foresters or forest engineers.



A cable-crane lifting a bundle of pulpwood
on to a conveyer (Mutare Board and Paper Mills)
(Photo: H. Seppänen)

3.3 Climate

Climate can affect both capital and operating costs in forest harvesting. Excessive snow in temperate climates and excessive rain in tropical climates can limit harvesting to a seasonal operation. Great heat or excessive rain may reduce productivity of both men and equipment even when they do not stop operations completely. Both shortened operating seasons and reduced productivity will require more men and equipment for any given level of production.



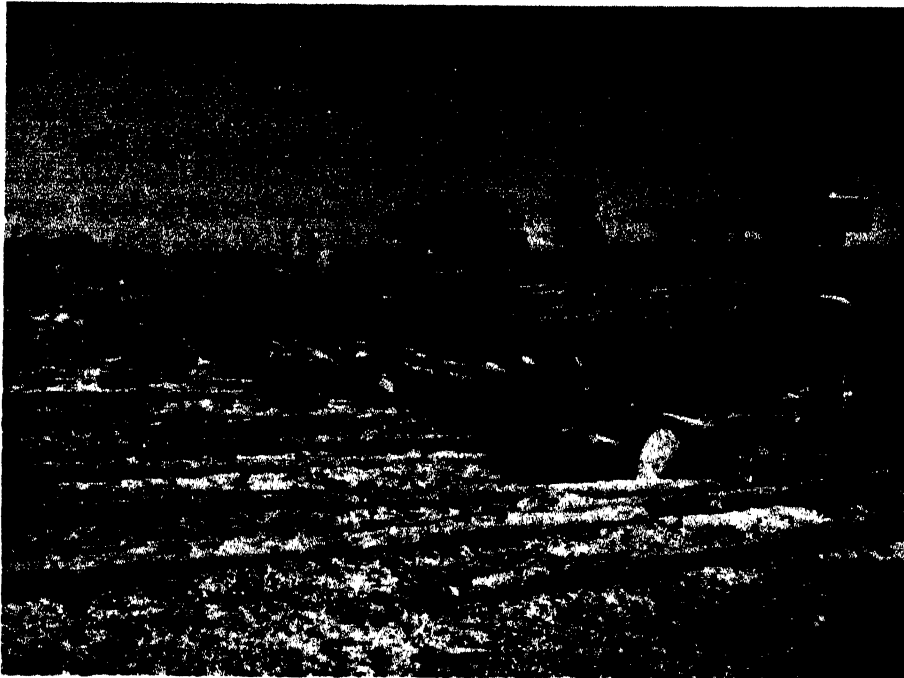
Manual loading of an agricultural tractor with trailer
(Forestry Commission, Erin Estate) (Photo: H. Seppänen)



Logs being lifted by a truck-mounted self-loading loader
using cable slings. The truck capacity was 8 m³.
Logs were unloaded by releasing the truck stakes
(Forestry Commission, Erin Estate) (Photo: H. Seppänen)

3.4 Infrastructure

The infrastructure developed in the wood supply region must also be considered in forest planning. The most obvious consideration is the extent to which roads, railways and water facilities exist and can be used in harvesting and thus reduce the need for new construction.



Logs unloaded at the mill logyard by driving
on to a ramp and releasing the side stakes
(Forestry Commission, Erin Estate) (Photo: H. Seppänen)

3.5 Workers and staff

The availability of suitable manpower is of great importance in developing the enterprise. If manpower is not available within the region, it must be recruited elsewhere; if skilled workers are not available they must be trained. Recruiting and training programmes must be planned and initiated well before sustained production is required. Provision of adequate trained staff may well be a major problem in developing a new enterprise. Many pioneering ventures have found it necessary to employ skilled workers and experienced managers and supervisors from other regions or other countries until local personnel have been adequately trained.

3.6 Laws, regulations and customs

Development of an enterprise may be affected by laws, regulations and customs covering a wide variety of subjects. Some of these may be common to many regions; others may be peculiar to a single region. All must be taken into account in planning for the enterprise. Those most frequently found to affect forest development include:

- wage or salary rates
- social benefits
- hours of work per day

- number of holidays per year
- forest use regulations
- environmental restraints
- government dues for timber
- scaling and grading rules
- waterway use regulations and fees
- road use regulations and fees
- railway freight rates
- taxes on fuel, oil and lubricants
- duties and taxes on equipment
- import restrictions
- development incentives.

3.7 Equipment performance, productivity, cost and availability

Planning a forest harvesting operation requires a thorough knowledge of the performance, productivity, cost and availability of the machines used in logging, log transportation, road construction and maintenance, and all the phases of forest harvesting. Only through such knowledge can the machines be selected, the required quantities determined, and a purchasing programme planned. There is no certain formula which will ensure the selection of equipment which will yield the lowest overall cost. Equipment selection will remain a problem throughout the life of the project. The best solution is to place the responsibility for it on men thoroughly experienced in forest harvesting and machine use. If such men are not available in the project area, arrangements should be made to obtain outside help.

4. PRE-OPERATIONAL PLANNING

Planning the wood supply for a forest enterprise is usually initiated with a feasibility study. Once feasibility has been established, the initial planning must be elaborated to include schedules showing the time at which each activity should commence to ensure that the enterprise will have an adequate supply of wood from the day it begins to operate.

4.1 Selection of the operational area and the harvest volume

Virtually all of the considerations discussed in Section 3 enter into the selection of the logging system and the logging equipment for a particular project.

In the selection of a logging system, most of the alternatives can be easily eliminated. Manual systems are not applicable in high wage areas and animal systems can be used only where suitable animals can be reared and where men are willing to train and care for them. Skidders are not likely to be satisfactory in steep terrain nor cable systems on flat lands. Light cable cranes are not satisfactory where the timber is large and heavy and long logs must be produced. Sophisticated machinery is unlikely to be satisfactory where maintenance facilities and trained specialists are scarce or where technological development is at an early stage.

Even after all the obvious alternatives have been eliminated, there will still be a wide choice of systems. The final choice will depend on the judgement and experience of the planning team. The wider the experience, the better the judgement will be. In selecting the makes and models of equipment for the system, particular attention must be paid to performance history and to the availability of service facilities and spare parts depots.

Selection of the transportation system is usually quite simple. Waterways, if they are available, provide relatively cheap transportation, particularly over long distances. Public carrier railways may also form part of the transportation chain. In nearly every case, however, roads and trucks must be used either to feed a waterway or railway or to carry the wood directly to the mill. The final choice between use of trucks and rail or water or trucks throughout must be based on cost (including cost of transferring from truck to rail or water) and reliability of services.

There is a vast array of equipment available for road transport and for loading trucks. Timber, terrain, logging methods, road standards, road use regulations, log length specifications, log weight and haul distance, all influence the type of equipment which should be used. The loading equipment should be carefully selected to ensure that delays in loading do not increase the overall cost of transport.

4.2 Equipment requirements

Once the logging and transportation systems have been decided and the equipment chosen, the next step is to calculate the number of units of each type which will be required. For logging equipment this can be determined from the harvest volume and estimates of annual productivity of each machine under the specific conditions of the projected enterprise. Transportation requirements can be calculated from truck capacities and estimates of the cycle time for each load. Considerations in determining cycle time include road quality, loading time, unloading time and average speed loaded and unloaded.

The need for construction equipment will depend on the extent to which the forests are served by existing roads and on the road spacing required for the selected logging system as well as on the nature of the terrain. Accurate estimates of the initial and annual amount of road construction must be prepared very early in the project. Because access roads may be needed, the amount of road construction is often highest in the initial years of the project, levelling down to a more or less constant rate in subsequent years. Selection of the types of construction equipment and determination of the number of units required must be made by engineers thoroughly experienced in road-building.

One of the functions most necessary to ensure an efficient harvesting operation is the repair and maintenance of production equipment. The facilities which must be provided can range from fuel and lubricant storage with field service vehicles to large workshops capable of carrying out complete overhauls and even some fabrication.

In addition to the major equipment a great deal of miscellaneous equipment is required. Examples include equipment for surveying and engineering, for crew and supervisor transport, for communication, for office work, for training and for safety and first aid. All of the equipment, both major and minor, must be specified and scheduled in the pre-operational plan.

It is not always necessary for the enterprise itself to purchase all the equipment needed. In many regions, contractors and service organizations with their own equipment are available for some of the work. This is particularly true for log transportation, for road construction, and for repair and maintenance, as there is usually a demand for similar services in other fields. The production plan should include as much use of these contractors as is consistent with an assured supply of wood for the mill. Complete reliance on contractors is seldom a good idea, however, as control of costs and production schedules is greatly weakened.

4.3 Manning tables and staff organization

The two major production activities - logging and log transportation - and the two major support functions - road construction and equipment servicing - will require workers in a wide variety of occupations. These range from unskilled labourers through winch drivers, powersaw men and heavy equipment operators to engineering technicians and highly skilled tradesmen. Other activities such as office work, first aid, reforestation and fire protection will require men with additional skills.

By analysing the production targets and the equipment already selected, the planners must produce a manning table showing all the various job categories as well as the number of workers in each category. Similarly, the planners must develop a management and supervisory organization which will ensure that all the functions will be carried out in accordance with project objectives.

Wage rates, salary levels and social benefits commensurate with the customs of the region, the responsibilities of the positions, and the difficulties of recruiting must be established as part of the operational plans.

4.4 Recruiting, training and purchasing

At this point, the planners will have defined the manpower and equipment which must be mobilized and the facilities which must be constructed before logs can be delivered to the conversion plant. To ensure that wood will be available on the start-up date, men must be recruited and trained; equipment must be purchased and delivered; and roads and buildings must be constructed. All these activities must commence long before the start-up date.

Planners must prepare estimates of the time which will be required first to recruit and then to train the required work force. Training courses must be prepared and training facilities developed. Some categories of workers will be required before others and the time required for recruiting and training will vary from skill to skill. In all cases, planners must prepare schedules which will ensure that trained men are available as they are needed.

Similar considerations apply to the purchase of equipment. Some machines will be required before others.

SELECTION OF LOGGING SYSTEMS AND MACHINERY

by

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1. INTRODUCTION

The selection of logging systems and machinery or equipment which are suitable for harvesting a given forest is not a simple matter. If raw materials are to be produced for conversion plants directly, or for sale, at a cost which yields an economic benefit to the producer, it is essential that the appropriate system be used.

There is some confusion as to what a system is. To some the expression means the type of product to be manufactured and the means to do it, while to others it means simply the mechanical or manual methods employed for logging. The term "logging" itself may give rise to confusion. It is considered by some to be the physical movement of logs from the stump to the loading site whereas in fact the physical capabilities of a logging operation range from cruising to final sales of the logs and in many cases include the forestry aspects.

A logging system is taken to mean a set or arrangement of items related to one another so as to form a unity or whole. It is also used in the sense of a method or plan of classification. All units or items in a system contribute something to the objective which is common to all. A systems approach is one that details the interrelationships among various components and their contribution to the common goal.

In this paper so as not to be too rigid, both concepts of a system are accepted.

Before a system or method or the machinery to carry out an operation is chosen, the planner or promoter must take a rational look at the existing situation. It is hoped that this paper will help to clarify the planner's thoughts or at least make him aware of the number of options available and some of the pitfalls which may be encountered in the process of selection.

It will not go into the methods of estimating productivity and costs, which the planner needs to know when selecting the best system or equipment for an operation.

Machinery manufacturers produce equipment which will be used as one or more links in a logging system. For the most part these manufacturers are responsible, well-meaning people, trying to put out a product which will perform a specific task within a system at the lowest possible unit cost. Many will modify their equipment to suit particular needs and many have been in the forefront of development of machinery for new systems.

There are usually many manufacturers of machines for any particular use. Anyone contemplating buying must be careful to buy the ones which meet his needs, not only for basic productivity but also for reliability.

Machinery manufacturers are out to sell a product, just as the logger is; but the logger buys a unit for the long term whereas he sells his product in the short term. His choice must be the best he can make or his venture may fail. Reliable manufacturers have been in the business long enough to provide equipment for any job at all, for they design from experience and feedback from dealers. What they do not or cannot always do is provide sufficient information on the applicability of their machines to one logger's specific needs. In their quest to sell their particular product they may advise purchase of machinery which does not fit into a system of harvesting appropriate to the forest in question, and ignore other considerations such as too much sophistication, or environmental and social issues.

The major objective of any harvesting operation is to produce logs at an economic price compatible with company aims, government policy and environmental aspects. Bearing all these in mind and giving them due consideration, the logger must choose the most appropriate system, or combination of methods and machines suitable for production of the product he has in mind.

For too long, planners have assumed that anyone can log, simply because "even our forefathers did it with their backs and with oxen". The real situation is quite the contrary: the industrial organizer must ensure that he hires or buys the best expertise and equipment. When a log enters the mill it has cost more than double what was paid for it in cold cash, because of the conversion factor, to which must be added the milling cost, normally lower than the price of the log before conversion. The cost of the log is usually the single biggest cost factor in a mechanical wood based industry.

It must be pointed out that even a simple logging/sawmill unit can cost some US\$10 million, and that a modest 150,000-m³ log/saw/plymill complex can cost US\$30 million and more; for such production, over US\$5 million may be needed for the logging component alone. The entrepreneur's decisions must be right the first time; second chances do not always come along.

Before anyone can begin to make final selections certain preliminary steps must be taken. These are covered in the next section.

2. THE PRELIMINARY STEPS

Prior to embarking on any venture, whether it be logging or a completely integrated industry, the potential entrepreneur must look at:

- the forest resources and natural conditions;
- the market;
- the financing to marry the two.

These three can be further broken down into numerous sub-factors, not all of which can be investigated by one type of expertise. These sub-factors will be listed and followed by a short discourse on the positive aspects and the pitfalls which may ensue if investigations are not carried out, or not carried out properly.

It must be remembered that no step can be divorced from another and although the factors are given in sequence they must all be borne in mind when an evaluation is made.

2.1 Inventory

An inventory of the forest is the most important preliminary step and requires special skills. In most countries, forest services are capable of carrying it out, but they may not put the correct emphasis, from your point of view, into their work. For instance, many people spend a lot of time gathering precise volumetric detail when the most important aspect may be species - for often that is where the money lies. Defect and breakage studies must accompany an inventory which will be used as the basis for planning a forest industry.

An inventory must be accompanied by a correct and detailed analysis. Again, more skills than those of just an inventory man are generally required.

The results of analysis of an inventory complete with volume, decay, breakage and species detail may be sufficient to stop a project if it is being analysed in financial terms alone.

Apart from loggable volumes and species, the inventory results must be analysed for details of weight (green for loading, hauling or floating), bark thickness and susceptibility to insect and fungus attack, in addition to marketability and determination of market value. Much of this detail, such as green and dry weights and susceptibility, is already available, but if it is not, the inventory required to gather it will be more complex.

The logger is interested in unit merchantable volumes which can be used to estimate logging costs and road density, among other things. The pulpmill man will usually want to know the total recoverable volumes down to a lower diameter limit than a sawmiller and he may want more details on the colour of the wood and silica content.

Although system planning and equipment purchases are normally carried out on the basis of a forest inventory, an operational cruise (enumeration) can be extremely useful and often essential, and since it must be done before operations start, it would be wise to conduct the cruise for the first year of operation prior to choosing equipment.

Inventory crews and expertise are not always to hand, but the expertise may readily be hired from numerous consulting firms. The potential entrepreneur must, however, know what he wants and what will be enough to suit his needs before he can properly direct the people he hires.

In some cases FAO can provide much of the expertise needed through one or more of its service programmes; but this assistance is normally limited to governments of member countries. State-run enterprises may qualify for FAO's assistance or guidance through requests made through their governments.

2.2 Natural conditions

The operational efficiency of most logging equipment is heavily affected by the natural conditions and forces found in the forest area. Thus, such factors as terrain, soil, availability of road surfacing material and precipitation must be determined before the system and machinery are selected.

For instance, fragile soils liable to erosion in a high rainfall area, on steep and broken terrain, may rule out the use of a skidder/tractor system. Soils in which compaction may be detrimental to growth of the next crop may necessitate the use of low ground-pressure equipment or cable systems.

In order to get this information, further work must be carried out and another set of specialists will be required.

Terrain conditions can be obtained with reasonable accuracy from topographic maps made from aerial photographs, but a dense tropical forest canopy normally hides minor variations such as low steep-sided hills which often become a costly embarrassment when road construction is started. For such areas, topographic maps constructed from details gathered by a topographic crew (which can operate with the operational cruise crews) are much better, but this system is more expensive than using maps made from aerial photographs.

Regardless of cost, topographic maps and terrain information are in most cases a necessity for proper planning and for equipment selection. For instance, steep terrain may necessitate the use of a cable system and yet the forest may not be the type which can be logged effectively with this system, especially if a selection management regime is required by the silviculturists.

Investigating soil conditions and soil typing can be relatively inexpensive provided only mechanical qualities are required, but if growth capabilities are also needed the costs will be much higher. Soil-bearing tests provide extremely useful information on the amount of gravel required for a road, and thus the number of trucks, loaders and spreaders which will be required can be estimated. The need for a large amount of gravel will influence the size of the gravel trucks and logging trucks as well as their number.

The availability of gravel or other suitable road surfacing material (laterite, rock, coral) or the lack of it will influence the transport mode (road, river) to be selected and shorten or lengthen skidding distances.

A complete absence of gravel in a high-rainfall area, and thus excessive road construction/hauling costs, may force the decision to use a cable system with a minimal number of roads, provided the silvicultural system will tolerate its use. If the silvicultural prescription cannot be changed then the problem becomes social and/or environmental and subsidies may be required or the enterprise abandoned. An alternative to gravelled roads is the limiting of hauling operations to the dry seasons, which will no doubt raise costs.

Soil seriously affected by rain and the churning effect of ground-working equipment can soon be in such a state that the machines cannot continue to work. Often long halts are required with resultant lost productivity and high unit production costs. The fixed cost of equipment, which continues to pile up, is not the only culprit; the large overhead charges usually also continue. If workers are laid off, social damage results.

Another fact which is often overlooked is the effect of rain and snow on the productivity of workers. In some countries work ceases when rain starts. Rain causes slower work through reduced vision and poor footing, especially on steep terrain. The chances of injury or accidents are greater under these conditions.

2.3 Environmental considerations

The effects of run-off, especially when it is forced into unnatural channels by roads and skid trails, are well known.

High precipitation coupled with certain types of logging and road construction equipment can prove disastrous to downstream areas and habitats. Careful planning and road layout and construction methods can often eliminate much or most of this so-called logging problem.

Rainfall data and stream flow data, along with a knowledge of downstream users, are as important for environmental reasons as for system selection and effects on the environment should have a bearing on system selection. The entrepreneur should begin to gather any additional data as soon as the idea to industrialize is conceived.

Similarly, the flora and fauna must be considered, and this requires more expertise if they are to be preserved. Logging disturbs animals, but, depending on its intensity, they may return as logging moves on. Some animals, however, need an undisturbed primary forest. A major factor to determine is what havoc logging is playing with the food source and its capacity to renew itself.

Environmental considerations may dictate that a forest is left untouched, as has happened in some countries. In many circumstances, however, government policy will prevail and logging for social reasons may be justified, in which case the logger must find the least damaging solution. In some countries, logging by balloons and helicopters is done for precisely this reason. Costlier road construction techniques are sometimes used to lessen the environmental impact.

The effect of many human actions on the environment has been largely overlooked in some countries, but recently more countries have developed environmental codes and it can be expected that logging activities will be included in the codes of many developing countries, as has happened in the developed ones.

The logger should ensure, or take steps to ensure, that he leaves the forest in a state in which it will produce another crop in addition to the other benefits which may be gained from it, provided that it is intended that it remain in forest and it is not being logged prior to clearance for agriculture or a dam flood basin. For this reason too, his selection of system and machinery is critical.

2.4 Government policy

The type and size of an operation will often be dictated by government policy. In richer countries the need to harvest the forests may not be as great as in poorer ones which need the employment and revenue. Countries well endowed with forests can better afford to harvest the standing wealth than those less endowed, since enough forest remains for other purposes such as recreation and conservation.

In any case, most governments keep the control of their forests in their hands and lay down the rules for their use. In order to change the rules, entrepreneurs must be able to show that their proposed type of operation will be advantageous to the country as a whole. This requires expertise and knowledge of any proposed system and equipment and its productivity, as well as its impact on the environment and social fabric.

2.5 Silvicultural system

The system laid down by silviculturists to ensure continuation of the growing capacity of a forest is one of the most important factors, along with marketability, governing the unit volume recoverable and thus the harvesting system and type of equipment to be used.

For instance, an inventory in a tropical rain forest might indicate volumes ranging from 45 m³ to 150 m³ per hectare of sizes suitable for industry; but the silvicultural prescription designed to ensure another crop and the presence of currently unwanted species, singly or together, may lower this volume to 20 m³ to 30 m³ per hectare. These lowered volumes paint a quite different picture of operating costs and road spacing.

A country would have to be either in dire circumstances or particularly well endowed with forests to disregard such a prescription designed to ensure the continuation of viable forest. Until the silviculturist can find another solution or works from a better data base, the logger will have to adapt. In order to adapt he must be knowledgeable or he must hire trained personnel to help pick the equipment which will do the job economically.

2.6 The industry or market

Loggers make a product for use in conversion plants, therefore they must know their log market just as industrial plants must know the markets for their products.

The industry or market to be supplied is one of the basic factors to be considered when systems are selected. Product length and size or diameter are major factors in system and machinery selection and are directly related to industry - for instance, veneer/plymills which normally use large sizes and pulpmills which generally use small sizes.

Marketing requires special expertise and while a logger does not usually have the same problems as a manufacturer who turns out many products, he must still be market-wise and this is much more important in the log export market where often the buyers are the loggers' only link to the outside world.

A logger must be flexible, in that he must be able to change with market needs. These may demand alteration in systems or techniques. In order to be flexible he must be informed, he must try to learn what the future holds vis-à-vis product needs or even fashion. This is not an easy task and may require that a marketing expert be employed. Small companies can, in some cases, keep at least partially informed by belonging to associations and subscribing to market-orientated publications or even observing what the competition does.

2.7 The work force

The selection of a system or machinery depends to a great extent on the quality of the work force, from management to labour.

Sophisticated systems and machinery require a well-trained work force to make them function to their designed or planned capacities. This training must be accompanied by experience if the optimum is to be reached. Other factors which also have great weight in selection are availability, attitudes, adaptability and health, along with body weight.

It may be appropriate to provide an example from my own experience. We were running a hand-logging labour-intensive operation in which the logs were carried from the stump to the riverbank on men's shoulders. One season the workers from our traditional supply villages were busy on their paddy harvest. Inventories were low and fast action was required. We hired men from other villages but soon found that they could not (maybe they would not) carry the logs on their shoulders and since the logs were too hard on the head and neck (their traditional method of carrying), we lost them all in short order. We managed, but just.

Any operation in the planning stage must give great importance to labour and should allow in its plans for training or retraining.

2.8 Financing

Without the necessary funds neither a logging nor an integrated enterprise can be successfully started. If they start under-funded and cash flows do not materialize as expected, the enterprise will fail, or someone else's money will have to be pumped in to save it. If the logger is lucky public moneys may be fed in for social reasons.

The logger can get financing only by proving his plan, ideas, markets and capability. In order to do this he must know how to draw up a plan, complete with equipment lists and production costs. These must be worked out to determine the feasibility of the proposal. Some enterprises or governments have the expertise to do this, but when they do not, consultant firms or individuals can be hired to do the job. Most financial institutions require that feasibility studies be carried out by independent, qualified outside parties.

Special knowledge of logging systems, equipment and its productivity, and overall planning are a prerequisite to performing such studies. If the expertise is not available, nor money to hire it, FAO can sometimes through its programmes provide Member Nations with assistance in this field, to the prefeasibility level. It can also act as a neutral monitor for these governments when feasibility studies have been completed by third parties.

A rule not to be forgotten is not to go in under-funded. Thus, reasonably accurate equipment prices with allowance for spares must be used in estimates. Similarly, equipment operating costs must be reasonably estimated, otherwise costs may be up and profits down, thus affecting the availability of operating funds.

One pitfall to avoid is buying the cheapest equipment when money is in short supply, for sometimes the equipment is not suitable and you are soon back in financial trouble.

Financial planning is one of the important functions which must be carried out when an operation is planned. Without sufficient original operating capital the venture can fail for lack of cash flowing from sales. This is often difficult to collect since sales are not controlled by the logger but by outside agencies. Financial planning, accounting and cost accounting must be a continuous process. Through careful analysis of operating techniques, costs and markets, the financial team can provide the advance information required to choose and to make changes in systems or methods.

Government policy with regard to foreign exchange is an important factor for some countries. In extreme cases, after the initial purchase has been financed there are no foreign funds available when spare parts are needed. This can be disastrous. It must be given serious consideration at the selection stage.

3. LOGGING SYSTEMS

Before a planner can begin to select a logging system suitable for his particular circumstances, he must evaluate the options available. The first type of choice may be broadly between manual or mechanical, where "manual" can include animal power and where there may be a certain amount of manual or mechanical function in either, to varying degrees.

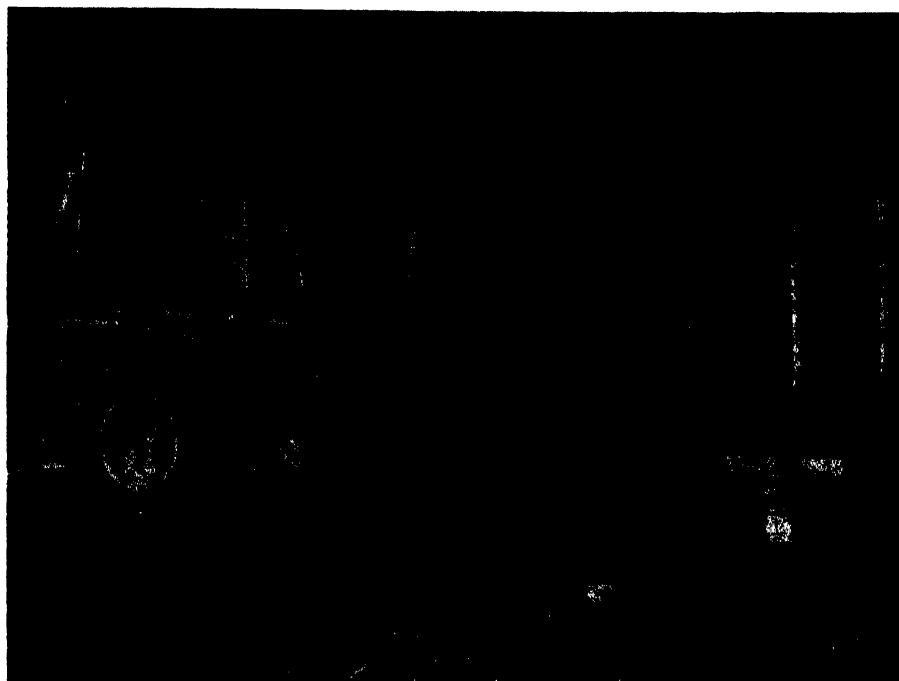
(Another more recent way of differentiating among logging systems is to name them according to length of products 1/, that is: whole tree, tree length, and short log to which I suppose could be added pulpwood and firewood.)



Manual loading of a trailer drawn by
an agricultural tractor. In the background,
a forest workers' village
(E.C. Meikle Private Ltd.) (Photo: H. Seppänen)

1/ A good description of these systems can be found in "Planning forest roads and harvesting systems", Forestry Paper No. 2, FAO, 1977.

Professor Ulf Sundberg has outlined a method of determining mechanical/manual requirements in a short paper published by FAO.^{1/} While this paper does not provide an easy way out, it does put the question in some perspective. It points out the need to know productivity and its relationship to costs, which one must know in order to select a system, method or machinery.



A locally-made trailer for an agricultural tractor
(E.C. Meikle Private Ltd.) (Photo: H. Seppänen)

A careful analysis of the items detailed in Section 2, plus others possibly unmentioned, should provide sufficient information to help in selecting which way to go, although the analysis can be complex.

Once a decision has been made as to whether the system should be manual or mechanical, it may be easy to choose a method if it is to be manual. Mechanical methods are not so easy to choose. In order to assist to some extent, this paper lists what some may call systems and others methods or sub-systems.

There are innumerable extraction methods and many machines that can be used to log a tract of timber and several can be grouped or linked together to form a logging system. Generally each machine performs a specific function within a system. Its purpose, however, is to fit into a chain of activities and events to produce logs at the lowest overall cost. There are certain machines which do not readily match up with others to form a system, yet in certain circumstances they may be an aid to clearing out difficult corners for a cable system, or be used as a mobile tailhold for a skyline cable system, or feed logs to a skyline system.

^{1/} "Level of mechanization in forest operations", FO:MISC/81/6, April 1981; 7 pp.

A system in this context, therefore, is a planned method of logging, from standing tree to final delivery point of the log; and pre-planning, inventories and engineering surveys are or should be a part of the system. This paper will confine itself to the production equipment aspect of logging systems, but it should be borne in mind that the preliminary steps enumerated earlier are a prerequisite to the use or selection of any system and equipment.

Since the groupings required to form a system are complex the paper will be confined to the major systems of extraction and transport - these two activities involve the most important equipment components of a system - and the ancillary or auxiliary functions which are also important but in most cases fit into any major extraction and transport system.

The (until recently) more standard systems are for the most part appropriate for indigenous tropical rain forests, but some are also suitable for the tropical and sub-tropical plantations which are now reaching maturity and ready for logging.^{1/} The latest and most highly sophisticated systems now in use in northern temperate coniferous forests, and aerial logging, will not be discussed. Long-distance transport is part of a system, and since it fits with any extraction system it will be treated separately.

3.1 Major extraction systems

The major extraction methods are by cable (off or partly off the ground); with a tractor/skidder (often called ground skidding); with semi-mechanical light equipment (such as the winch lorry ^{2/} of southeast Asia, farm tractors with or without forestry attachments); and manual/animal methods (swamp logging in some countries).

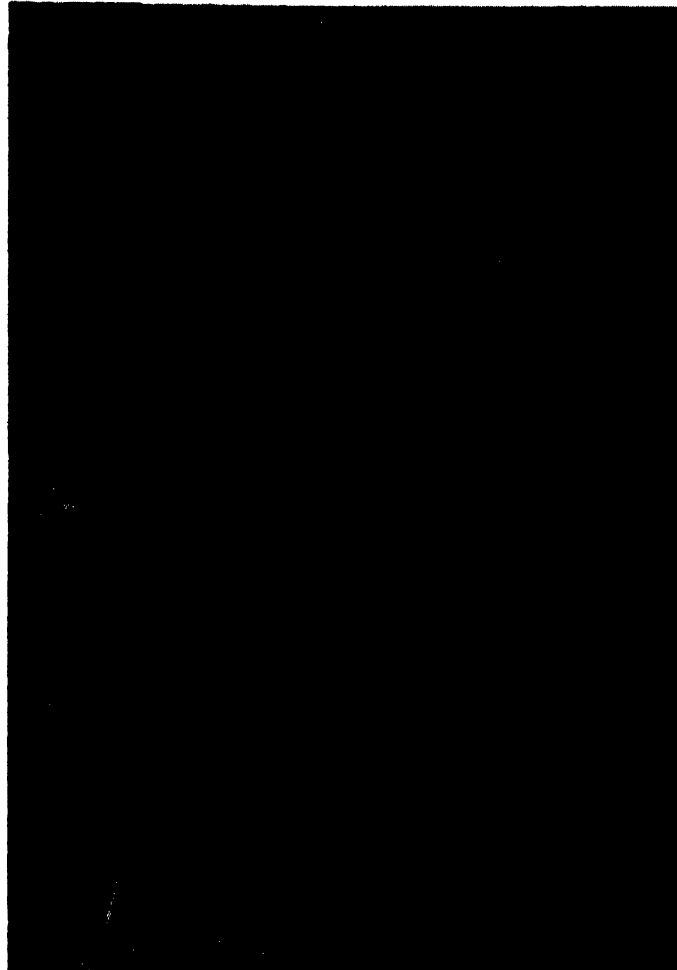
At this point it must be remembered that the extraction system cannot be divorced from the transport system and auxiliary functions such as felling and loading. Each will have an effect on the extraction system.

The problem of the planner/investor who has little experience is how to pick the system which will provide logs at the lowest cost and still be compatible with silvicultural and environmental needs, as well as adhere to government and/or company policies (for example, on employment, or foreign exchange). These three points, jointly or singly, will force a decision on the use of a certain system or method and in any case they will, or should, provide some of the answers to the handling of other criteria (unit volumes, soil considerations) which must then be brought into the selection analysis to form guidelines.

Each of the systems mentioned above is affected by certain criteria which differentiate it from the others. The effects of some of these criteria show on the balance sheet once the wrong system has been tested. Conversely, a selection which eliminates their bad effects or turns them to advantage has a positive effect on profits.

^{1/} See "Harvesting man-made forests in developing countries" FOI:TF-INT(SWE), for techniques and cost estimation. FAO, Rome, 1976.

^{2/} Details are given in FAO's papers FO:DP/MAL/72/009 Working Paper 29, June 1974 and "Self-loading winch trucks" Rome, 1984.



A 25-year-old Pinus taeda stand clearcut
using chainsaws (Border Timbers Ltd.)
(Photo: H. Seppänen)

The preliminary data, gathered in the initial stage, are the source for obtaining the conditions and/or figures necessary for an evaluation.

The major criteria which will influence the choice of system are:

- topographical conditions
- weather (precipitation, heat)
- soils
- silvicultural systems
- volume per area
- volume per log
- log size

and these must be considered when the planner attempts to rationalize a choice, for each system is sensitive to one or more of them. These criteria may include variables such as limbiness or defects in the trees.

Other criteria which enter into the calculation are:

- availability of manpower
- mechanical capability of personnel
- operational capability of personnel
- animal power, availability/experience
- accessibility/infrastructure.

These are self-explanatory. One would not normally choose the most sophisticated (and expensive) equipment if the available people are not mechanically inclined, unless for some policy reason the operator is willing to forego immediate profits until a training programme has remedied the situation. Normally in such cases, the operator starts with a less sophisticated system, where feasible, and works upward as experience is gained and as original equipment wears out or where special circumstances, such as a dwindling supply of workers, dictate. Accessibility is easily understood as a concept but can become a major problem as a factor affecting the selection of a transport system.

The major criteria defy a simple system of evaluation to show the relative effect of each as merits or demerits within each system or between systems. To do this, the interlinkages and variations within criteria must all be defined and would be the subject of a book, let alone this paper. Delineation is not so severe for one piece of equipment or system, but is excessive when systems are bridged. The best way to point out the effects of criteria is to handle them system by system and then let the reader draw his own conclusions for his particular circumstances.

3.1.1 Cable

There are many methods of cable logging.^{1/} The primary ones are "high lead" and "skyline" with innumerable variations, especially in the skyline method. Suffice it to say that they range from the heavy-duty systems in use on the west coast of North America, the Philippines and Borneo, to the lighter cable systems used in swampy ground in the southern USA and the numerous lighter skyline methods used predominantly in the mountainous regions of Europe and in a few developing countries in Latin America, Asia and Africa. It may be noted that loggers on the west coast of America are beginning to study and use the European systems as their supply of old growth timber diminishes.

Topographic conditions such as steep slopes and broken terrain are not a serious factor in cable logging - or at least, not as serious as in tractor logging. The biggest problem that such conditions impose on the system is mostly to do with labour which must be well trained and which can be unproductive in difficult terrain.

Cable systems have been used on ground which varies from flat to steep slopes. Level ground is not the best on which to use cables, especially the heavier systems, unless soil conditions so dictate. Because cable logging requires well trained and skilled operators it should, if possible, be limited to forest areas where no other extraction system can work satisfactorily.

^{1/} See FAO Forestry Paper No. 24, Cable logging systems, 1981.

Rainfall and snowfall are not excessively detrimental to such systems, but their effect on the loggers can drastically reduce production. Rainfall and its influence on soil hardly affect movement of the logs, since the heavy machinery is stationary. Incorrect planning in a high-lead system can lead to serious erosion.

Excessive heat can affect labour productivity, but this is common to any system.

The silvicultural system prescribed can be a factor limiting the use of cables. If a diameter limit selection system is imposed, not only will the volume possibly be lowered to the point where cable logging is uneconomic but to try to log selectively a few trees from among many standing ones without damaging or destroying the residual stand is a difficult task. Some prescription on damage to residuals, if rigidly enforced, could preclude the use of high-lead cable logging and some skyline systems.

Cable logging is best suited to clear-felling operations. In some areas where the forests are rich, heavy volumes are to be removed, and regeneration is assured, the system(s) can be used effectively.

The size of log dictates the size of the cable system, but since the fixed machine costs plus the fixed cost of time lost in setting up are often high, the size of the area to be logged (the setting) and the unit volumes per unit area are critical. The critical unit volume varies with regions and experience of the logging crews. The new, larger and costly west coast of North America portable systems have considerably reduced the moving and set-up time, but the volume over which these items must be written off is still a factor to be reckoned with.

The following is presented to give some idea of the volumes some companies are logging with high-lead systems in tropical hill forests in southeast Asia. One operator used high-lead on volumes of some 130 m³ per hectare and roughly 2 000 m³ per setting, while another stopped high-leading with approximately the same unit volumes but smaller total volume per setting, due to the broken terrain which reduced the area per setting. He found he could log more cheaply with tractors. At another location an operator was high-leading in some 50 m³ per hectare of forest on terrain which was not too steep, with an average volume in the order of 1 200 m³ per setting.

A report from the nineteen seventies indicates that certain Philippine loggers were high-leading in stands which yielded between 80 m³ and 100 m³ per hectare and with average setting sizes as small as 15 hectares. Some operators use two or more systems and therefore can afford certain high-cost operations which are necessary because of the terrain conditions and still reach an acceptable average delivered cost.

From the above it will be evident that the spread is wide. It must be noted that the tropical forests of southeast Asia are the richest in the world for the volume of merchantable timber to be removed per hectare.

The selling price of the log will determine how low a unit volume can be logged. If the logger can choose a cheaper system which is capable of efficient logging in low volume forest, profits will be higher.

Workers require special training to use the system, and experienced supervision is essential if the best techniques (tricks of the trade) are to be effectively employed.

For plantations, skyline systems can be effective and the light equipment of alpine Europe with multi-span skylines can allow longer set-ups (strips) and substantially reduce the amount of road required. On gentle, easy terrain, however, a skidder/crawler system is likely to prove cheaper.

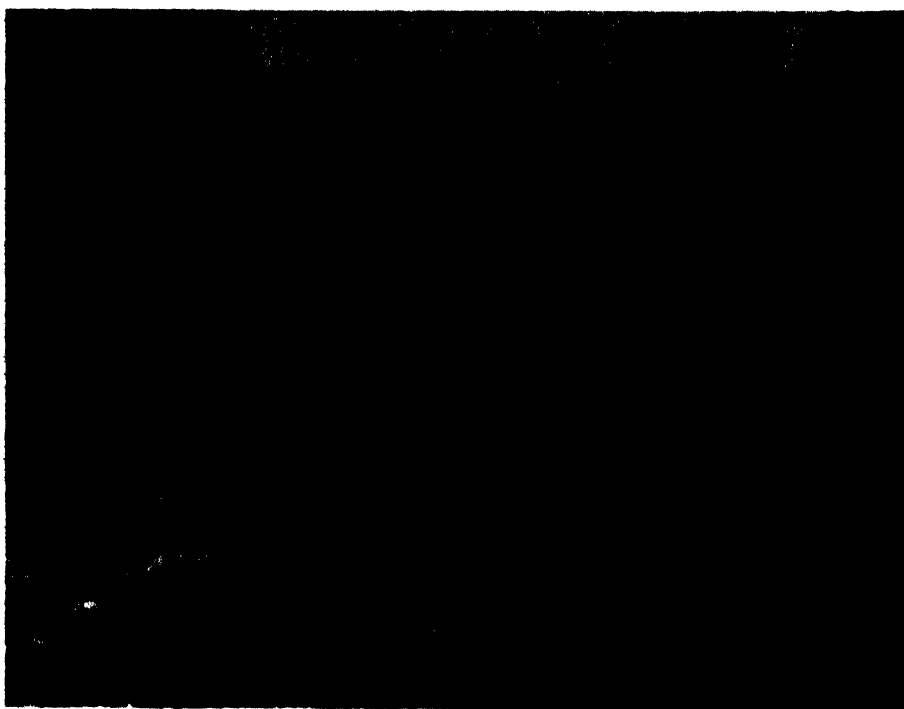
For single-span skylines the shape of the slopes to be logged is important. Without the deflection obtained by a concave shape the system cannot be used. This will indicate the need for accurate topographical maps.

The best advice one can give on the evaluation of cable logging is to bring in experienced loggers and forest engineers as assessors. They can be obtained from the Philippines, where high-lead logging in tropical forests has been going on for a long time, and from temperate countries for logging plantations.

3.1.2 Tractor/skidder

A term often applied to the system using this type of machine is "ground skidding". The fact that the skidding machine runs over the ground, dragging one end of the logs, gives one a picture of the effects of some of the major criteria on the system.

Tractors (crawler tractors) can be used alone or combined with another machine, the articulated four-wheel-drive skidder. They make an effective combination and in most cases the skidder cannot be used without the assistance of a crawler tractor. The ratio of crawlers to skidders generally varies with the terrain and log size; as a rule it is from 1:1 to 1:3.



A CAT D-40 crawler tractor used in skidding
Pinus taeda clearcut areas. The production was
approximately 60 m' a day over an average skidding
distance of 100 m (Border Timbers Ltd.)
(Photo: H. Seppänen)

Both machines (and therefore the system) are sensitive to terrain conditions. The crawler is limited to slopes of 40% to 60% but the upper limit should not be considered a norm, and adverse grades must be limited to about 15% to 20% and only for short distances which do not occur too frequently. I have seen large crawlers working on steep slopes skidding logs up skid trails in the order of 40% but production was low, and I have seen crawlers working slopes of over 60% but only by cutting skid roads across the slopes.



A CAT 518 rubber-tired skidder in clearcut operation. The production was about 120 m³ a day over an average skidding distance of 100 m. The logs were skidded in tree lengths and bucked at the roadside (Border Timbers Ltd.) (Photo: H. Seppänen)

The skidder is normally effective only on slopes of up to 40% but recently loggers have claimed going to 60% on select terrain, using grapples on bunched trees. This machine, which is intended for fast hauling, is sensitive to adverse grades since the lost time (or smaller load) resulting from the attempt to skid or winch a turn up such grades defeats the purpose of the machine (high productivity through its speed). Broken terrain thus becomes an important consideration in its use. Similarly the advantage to be gained by fast skidding over long distances is lost in adverse terrain and a consequence is that more high-class truck roads will be required. The introduction of the skidder to the ground skidding system did lower the amount of truck road required per area logged.

Soil types and the effect of water on them have an equally important bearing on skidding. Good, apparently firm, soils sometimes become quagmires when wet. In areas of high precipitation, a careful look must be taken at both these factors and their possible combination. Extremely wet conditions can either slow production per day or stop operations over days and periods of time.

Special wide flotation tyres are available for use under wet conditions and on fragile soils. Limiting the number of days a machine or machines in combination work raises the fixed charges and machine inventory carrying costs, sometimes to the point of making the operation unprofitable.

The tracked skidding machine which came on the market some 10 years ago has overcome some of the detrimental effects of water on skid ways and improved the adverse skidding capability of the machines while retaining the advantage of speed.^{1/} The machine is in use in some places in the tropics and is employed in a part of Canada to extend the reach of skidders up steeper slopes. Without going into great detail: the machine is essentially a high-speed tracked vehicle capable of operating in muddy conditions and on slopes of over 40%. It has an added advantage in that it exerts relatively low unit pressure on the ground.

Conventional ground skidding bares a lot of soil and can lead to serious erosion problems, but careful layout and training of operators can lessen this.

The effect of silvicultural prescription on this system is not as serious as for the high-lead cable system since the machines can manoeuvre among standing trees. Nevertheless, the use of machines which are too cumbersome can play havoc with the residual stand. These problems can be overcome with careful planning and supervision.

Crawler/skidder logging can be carried out profitably often at low volumes per hectare, but the high value of many tropical trees is a great help. There are virgin forests now being logged from which only 15 m³ per hectare are being harvested. Some rich forests of southeast Asia yield over 100 m³ per hectare. Generally the minimum volumes which can be logged or the point at which another careful look at all the other factors should be taken to see if they will alleviate the possible high costs, is in the order of 30 m³ per hectare.

The size of trees and/or logs dictates the size of tractors/skidders which should be chosen. The machines come in many sizes.

The ground skidding system has been in use around the world for a long time and the use of crawler tractors is common in other fields, therefore the chances are quite good that in most countries there will be expert crawler tractor operators. Skidder operators will be rarer and require special training even if they have previously operated crawlers.

3.1.3 Semi-mechanical/light mechanical systems

The heading for this section may appear strange; it is, however, intended to convey the idea that there are many pieces of equipment other than highly specialized and costly units, which function well under specific circumstances. These systems have a distinct advantage in that the components are not too sophisticated, nor are they usually too expensive relative to crawler/skidders. They also require more labour input which often meets a critical social need.

Normally these systems are not adequate to supply logs for large industrial operations since their relatively low productivity makes the logistics problem great. They can, however, often be an arm of a large operation, producing in special areas and at a low cost.

^{1/} Forestry and forest products development. FMC tracked skidder logging study in Indonesia.

Two systems which come to mind and are worth discussing are the winch-lorry system of southeast Asia and the farm-tractor ground skidding adaptation.

The winch-lorry system 1/ has been in use for some 30 years and has performed effectively on the easier types of terrain; with the move to the mountains which was required as the forests receded, the system adapted.

Originally a tractor was used only to build the crude roads, but on steep and often rugged terrain the tractor became the prime mover, bringing the log to the winch-lorry at the crude road. The ratio of winch-lorries to tractors is in the range of 3:1 to 7:1. The system is still in use in Malaysia and Indonesia. It is believed that the Philippines version called the "Bataan logger" is still in use but to a limited extent.

Terrain conditions are a limiting factor, with normal winch-lorry roads being limited to 30% grades, but I have seen them hauling down slopes of 50%. In one case the logger used logs as a drogue.

Adverse grades naturally also slow the lorry but since most winch-lorry roads are crude, the normal speed is slow. Adverse grades of 35% have been measured. .

Soil and the effect of water on it is important, but the six-wheel-drive feature permits the operation to start up soon after the rains stop. Production is definitely lower during the monsoon months. The machines are operated on contract or through an owner/operator contractual system, and as they are relatively cheap, down-time is not as important as for expensive machinery being operated by daily-paid workers.

The system can function on low unit volumes, as low as 8 m³ per hectare, and has been particularly effective in relogging as market trends for species change. I have seen an operator logging an area with a prebuilt rudimentary road network for the third time over and bringing out less than 5 m³ per hectare.

The system is unsophisticated and drivers and crew soon learn to repair all but the engine of the lorry, the tractor being as in any other system. It is labour-intensive and production costs are usually lower than in the major systems. The older machines have mostly worn out and higher-priced trucks are now being used, thus the machines may lose some of their cost advantage, although costs of other equipment are accelerating at the same rate. The system works well with medium-sized to large logs and has been used effectively in some plantations of south Australia.

Farm tractors adapted for skidding form another system which fills a need for inexpensive equipment and a high labour input. Manufacturers have made many accessories such as winches and towers (to form a cable unit) to fit farm tractors and they have become quite common in the United Kingdom and parts of Europe. They are limited to small trees and do well in logging plantations on moderate slopes, to, say, 30 %. The same limitations apply to these as to the winch-lorry.

1/ Details are given in FAO's papers FO:DP/MAL/72/009, Working Paper 29, June 1974, and "Self-loading winch trucks", Rome, 1984.

3.1.4 Manual/animal operations

A logger does not always have to buy motor-driven equipment to move logs from the stump to the carrier or dump.

An excellent example of the manual option is the kuda-kuda system of Borneo, where it is used to harvest freshwater swamp forests. Until about 15 years ago the tree was even felled by hand saw and axe. The sole concession to power, other than human, is a miniature railroad with skeleton cars pulled by a small, used, diesel mine locomotive.

Many push/pull, slide/roll logging operations still exist and produce logs more cheaply than is normally the case with high-powered and complex machinery. Over and above axes, wedges, levers and jacks, manufacturers make sleds, chutes and pans pulled by radio-controlled winches and the like. Some mangrove forests are still being harvested using human power carrying or pushing the log on a wheelbarrow.

Animal pulling power has only recently left some of the temperate areas and some countries are in the process of training oxen for log skidding. ^{1/} Elephants are still used extensively in Asia. The manual systems are not dead and areas are yet to be found where they fit the bill. A problem is that as people get more sophisticated they want change, and everyone likes to do work which is less physically demanding. The logistical problems of supplying a large industrial complex using manual/animal systems can be great.

One thing which should be evident from this review of the basic extraction systems is that ground and cable systems are not readily comparable because they have been developed to operate in different circumstances. In actual operating conditions many loggers soon determine which is the best system as far as they are concerned, though they may be biased through earlier training or the particular circumstances or physical criteria of the forest they originally started in. One thing is certain - training followed by experience is the surest foundation on which to base the choice of a method.

With a knowledge of his forest and its environs the logger should be able to identify the system that will most probably be suitable. The number of individual pieces of equipment needed within a system is only a matter of numbers, sizes and configurations.

3.2 Major transport modes

The other major aspect of any logging system is transport. Each of the transport systems listed below can be used with any of the extraction systems enumerated earlier. The appropriate one must be chosen. Sometimes there is no choice but one, and its use is obvious.

There are three ways to move logs over long distances: by truck, by rail and by water. The criteria for extraction methods apply to transport as well, but as will be evident, accessibility and availability of infrastructure and waterways become a key issue.

^{1/} Wood extraction with oxen and agricultural tractors, FAO Forestry Paper 49, Rome, 1986.

A logger should think twice before going in to log an area which is very remote. If there are no public or private roads or a railroad within economic hauling distance from the forest, the extra cost of constructing a lengthy access road often deters the investor. The presence of good, usable public roads often changes the picture; for instance, logs have been hauled from 3 000 to 4 000 km in Brazil, although they were of selected species and at back-haul rates. Wood-hungry industries in parts of Asia haul logs from 160 to 500 km.

Basic data collection therefore must include information on public roads, railways and waterways which may include coastal and seagoing movement. Occasionally other information is required on port capabilities, rules, shipping and handling rates. Basic data yield the information required to tell what method(s) should be used to get the lowest costs.

The chief mode of transport is now trucking, for accessible forests have almost completely disappeared from the vicinity of coasts, rivers and railways. Occasionally all three methods are used to move the same log; it may be trucked to rail, railed to water and floated to the mill. Generally, however, two systems are the norm when systems are combined. In most parts of the world where water transport is used, the logs must first be trucked. Certain parts of Amazonia are still producing large quantities of logs without the use of trucks.

Once logs are loaded on to a truck, it is a simple matter to get it on to a public road and deliver direct from the forest to the mill yard, provided the distance is not excessive. The movement is positive - logged today and at the mill today or tomorrow. Tacking on another mode involves extra handling and delays and the manager often loses some control over his log for periods of time.

Railroads are a cheap method of moving logs, but the logging railroad has almost become extinct because of its inflexibility with regard to terrain, and public railroads do not often go to or through the forest. Where available, railroad haulage can be cost-effective.

For the three modes - water, rail and truck - the costs per unit of log, especially for long-distance movement, are in the ratio of approximately 1:1.5 to 2.5:3.5 to 5 respectively. Naturally there are great variations for efficiency and ratio of fixed time (loading, unloading, terminal costs) to hauling time, plus load factors affected by regulations and road conditions, stowage and service. Hauling costs are sometimes higher on inefficient railways than they would be by truck. Road, spur and loading facility costs are extra in all cases.

The various factors which affect transport costs are time, distance, terrain and weight (volume). The interplay among these items will be readily seen. For instance, a road with poor alignment and a low carrying capacity due to difficult terrain conditions and lack of surfacing material will impose low speeds (time) and less will be carried per trip (weight/volume). Similarly, on a winding, slow-flowing river, barges will travel more slowly and costs will be higher than on a straight, fast-flowing river.

These factors need not affect each transport mode to the same degree. For instance, on a twisting road or river the logger may be able to increase the load size, so partially lowering the increase in unit costs due to time.

If the unit cost per m³ of transport were calculated for the three modes over varying distances a graph could be plotted which might look something like the one in Fig. 1. One must remember that there can be great variations.

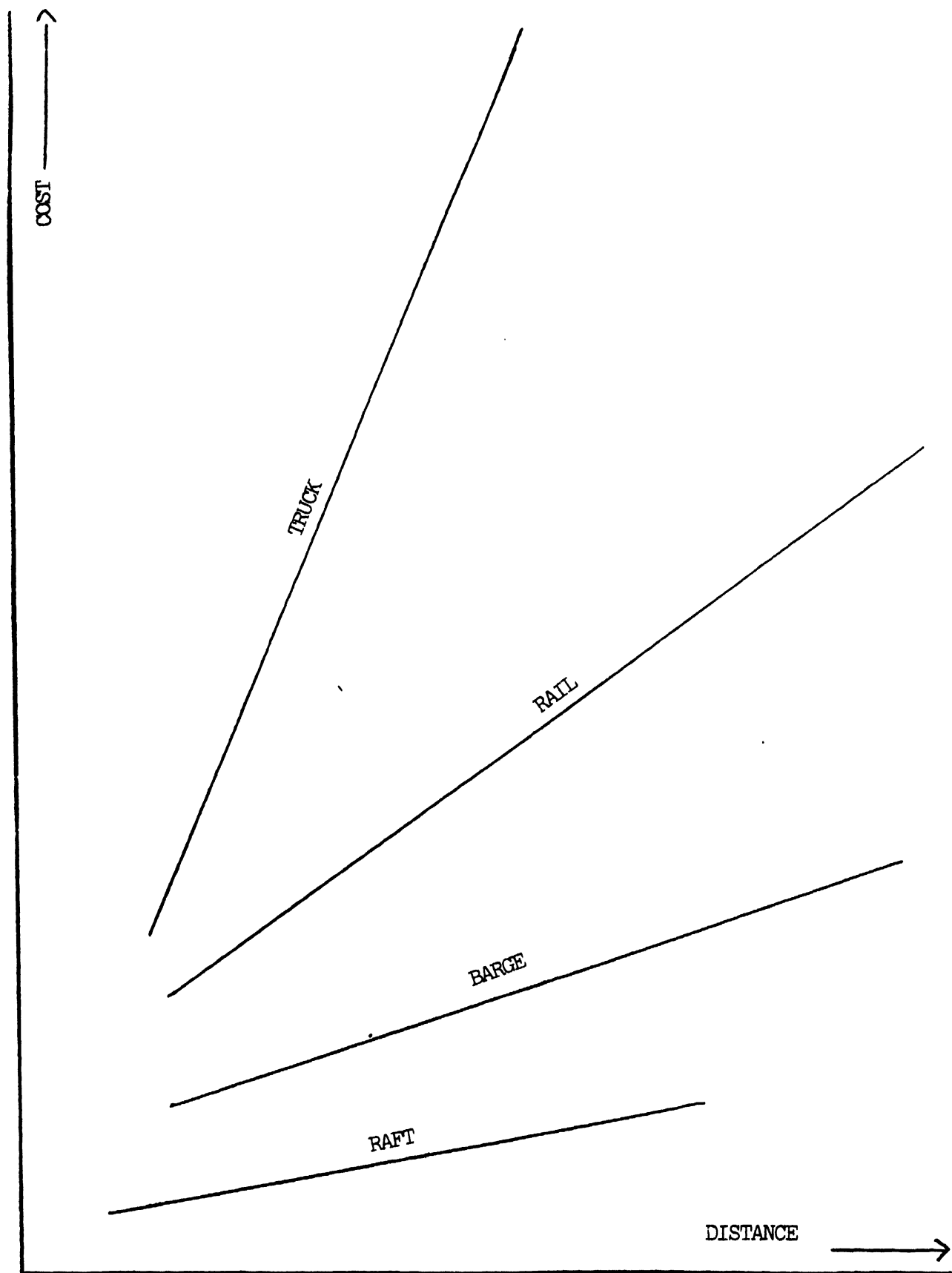


FIG. 1 LOG TRANSPORT COST RELATIONSHIPS

3.2.1 Trucks

Truck hauling is sensitive to soils and water, and thus to the availability of surfacing material for all-weather haulage. The truck is much more versatile than rail in difficult terrain conditions, but the cost of forest roads and their maintenance must be added to hauling costs. In most cases, however, roads are necessary anyway for a first move.

Once it has been decided that trucking is necessary and/or desirable, a careful look must be taken at the units to be purchased. Trucks come in many sizes and configurations. Their use is now so prevalent that many firms manufacture trucks and trailers just for logging. They are generally in the heavy-duty range and the cost of one unit can run from US\$100 000 to US\$200 000, ex-factory. Trucks in the medium- and light-duty range are usually assembly-line units with perhaps some special features such as strengthened frames, heavier suspensions and axles, and different rear ends and gear ratios.

The size of the operations and the operational periods and shifts are basic to any calculation; limits on public roads (and on some private ones) are equally important in the final selection. Some trucks, without load, weigh as much as permissible gross vehicle weights on the low-standard public roads often found near forest areas. Some manufacturers use lightweight materials so as to allow an increased payload. A system of trailers can increase the payload, but a careful look must be taken before this arrangement is adopted, for the logistics are not simple and the roads must be special and of high standard.

The driving/operating capabilities of operators will often govern the choice of size and accessories (automatic, power shift and power steering), since huge trucks and long loads are difficult for inexperienced personnel to manoeuvre. Low forest-road standards may indicate the need for front-wheel drive and load limits are usually higher for more axles. Three-axle trailers which function like a pole trailer and track equally well, and which increase highway payloads by 17-20%, are now coming increasingly into use.

Loading and unloading methods can also be critical. A small operation cannot always afford to employ or buy a fast mechanical loader, therefore loading can take up to four or five hours. It is pointless and costly to have a huge expensive truck standing waiting to be loaded. Or a pole trailer which is normally loaded for the return trip sometimes cannot be loaded or unloaded for lack of a sufficiently strong loader. In many parts of the developing world logs are loaded manually or semi-manually, or at least without the benefit of separate special loaders. Whatever the loading system(s) used, the truck should be bought to fit not only with it but also into the overall transport system.

Truck hauling is often the most expensive phase of logging, so it is only right to take special care in the selection of trucks and their configuration. Expertise is available, not only for the initial selection but also for the effective operation of hauling. Some companies employ full-time transport superintendents. As stated earlier, most truck manufacturers have the expertise to supply the truck, but the logger must know his requirements and have the basic data at hand.

He must know the terrain to determine the type of road he will build; sharp curves and steep grades demand certain specific equipment, including trailers. The size of log desired by industry and the size of the trees will perhaps require special features capable of handling, say, long logs. The size of the truck and the extraction equipment must be well matched for the best overall performance.

Highway hauls require that the operator know all the regulations, those pertaining not only to speed and gross weights but also to size, such as overall length, width and height. Quite often there are antiquated rules which no longer fit the situation. A well outlined and calculated case may assist the authorities to update their regulations or get the operator special hauling permits that will save money.

3.2.2 Railways

Above a certain distance, hauling by rail is usually cheaper than by truck. In many cases, however, the rail haul involves a truck haul at both ends, therefore a careful look must be taken into these added costs, which include rehandling.

In some countries rail hauling on public systems is not as efficient as truck hauling, and private railroads into the forest area are usually not viable because of the difficult terrain found in most remaining forests. Because of this it is doubtful that anyone still extracts directly to a railroad, an exception being the mini-railways of the swamp forests of southeast Asia, which are the only ground haul methods suitable and which usually haul only short distances to the nearest river.

With the now increased and until very recently continually increasing price of fuel, it is possible that companies have already looked or will look into the possibility of putting in rail for their long hauls. Remote areas, far in the hinterlands, will probably best be served by rail put in for another purpose, say, for mining. In all public rail hauls the logger is at the mercy of the railroad and generally railroaders have not given much time or effort to help solve loggers' transport problems. Railroaders often claim that loggers are inconsistent. Perhaps it is the loggers' own fault that they are inconsistent; perhaps this is a result of government forest-licensing policy.

The rate structure on public railroads is usually complex. Railways play a prominent part in the overall economic policy of some countries and often these policies are reflected in the rates for certain goods or commodities. The same can apply to internal water transport, and to some extent trucking on public roads, where rates are levied to meet a specific need or encourage/discourage certain activities, often as a market regulatory tool. Before investing in equipment, a logger who must rely on rail for his long haul should ensure that he has a long-term agreement, with procedures laid down on how to handle any rate alterations.

Rail transport requires special expertise if the operator is to operate a private railroad. On public roads the figures can readily be obtained but during preliminary discussions he must ask all the appropriate questions. Railway people tend to assume that the operator knows as much as they do. Some unmentioned items can be costly. Are the public railways willing to put into service special railway wagons which will handle logs most effectively? Often, they will not. One skeleton car can cost more than US\$20 000; cars sit idle for a good part of the time, in addition to which the logger may have to pay deadheading charges.

Public railways (like public roads) have set load limits which must be carefully considered when calculations are made. Green weights and bark can make a haul expensive, especially if the wrong cars are used and load configuration is regulated, say, to pyramid only.

Until recently at least, road transport of other commodities has cut into the railway business so badly that many have become unprofitable. Where rail service is available a careful look should be taken into its use, especially for long hauls. If a logger would have to build private roads over great distances served by a railroad, the rail haul would normally be a better option, unless service is too unreliable.

3.2.3 Water transport

Water transport has always been the most economic method of moving logs, but the water system is not always available in the forest. In some areas, using rivers to float logs is prohibited for environmental/ecological reasons; in some others it is considered a public nuisance and danger because of the deposition of deadheads.

Ocean transport is a specialized business and implies moving logs out for manufacture in another country, therefore it will not be covered here. It should be mentioned, however, that Indonesia, the Philippines and Brazil, for instance, have vast distances which can be covered within their territorial waters. An examination of these would constitute a complete transport study.

Traditional water transport entails floating the logs in controlled groups on rivers without use of equipment or towing log rafts and/or bundles and barges with tugs.

The former method is gradually disappearing along with the river drives of the northern coniferous forests. Rafting and barging are still quite common though mostly restricted to countries well endowed with rivers and/or a sea. In Indonesia vast amounts of logs move down the rivers to tidewater ocean shipping points or mills. Similarly, most logs in Amazonian Brazil move on the Amazon or its tributaries and the major rivers of Africa are used to move logs to tidewater.

For obvious reasons a logger must know the green weights of his trees and the conditions of his rivers or the sea. Remote forest areas can appear accessible until one observes the river-flows during the often prolonged dry season. Fast river-flows can preclude towing upstream or raise costs considerably.

Tugs used for towing or pushing must be especially designed for a particular application. Although one sees "any old boat" towing log rafts and barges in many countries, they are not often the most efficient. Their main advantage is that they are already owned or that the owner has a lot of empty time and will charter out at low rate.

Tugs used for moving logs come in all sizes, and power sources range from less than 75 kW to big barge puller/pushers of over 1 200 kW, depending on the application. Initial capital outlay for a barge/tug system can run to a sizeable amount; for instance, the cost of a tug (towing/pushing) and two 2,000-ton-capacity barges can amount to US\$ 1.5 million, depending on the country of construction.

When log barging is being considered an important factor is the stowage. A between-decks or welled barge will not usually handle as many logs in volume as a flat-decked deck-loaded scow, and loading is simpler on an open deck.

Regardless of the high figures quoted above, if the logger has a floatable/navigable river it is essential to investigate its use. At the same time boat crew staffing and government manning regulations should be checked. The rules sometimes force an operator into more capital and operating outlay than he envisaged and thus higher costs. For coastal or deep-sea shipping, an operator can sometimes negotiate or force lower rates.

In areas with good rivers and coastal waters along with a forest which supplies logs that float, simple rafting systems are most often the answer. The surest and fastest method is to tow the flat or bundled rafts of logs; although losses may be high in flat rafts. Again, especially designed tow boats are the most efficient.

Logs stored in salt water for long periods may be degraded by marine borers.

3.3 Forest roads

Forest roads form an important part of the truck transport system. In general it can be said that the factors which affect cost of extraction by crawler will have a similar effect on road subgrade construction equipment, where crawlers predominate. A tendency which has appeared of late is the use of power shovels called excavators or back hoes for subgrade construction. This could well be the answer in some problematic soils in the tropics and could also help to alleviate environmental problems associated with or caused by the crawler method of construction. Some studies are said to show that the cost of construction using an excavator is cheaper than using a bulldozer.

Surfacing and grading equipment are standard, but the size of gravel trucks may cause a minor selection problem in order to balance out the loading. If gravel is applied only lightly and over a short period, the trucks might stand idle unless they can be turned to other use. In such circumstances, an operator might be better advised to hire or contract his trucks and loader for the requisite period, if he can.

Road construction is a specialized task requiring a lot of supervision, so much so that most large, well run companies employ a road foreman.

4. ANCILLARY PRODUCTION FUNCTIONS

Although these functions have been listed in this paper as subordinate they are by no means insignificant, and if not properly carried out can disrupt an operation to the point where production is drastically lowered or costs are raised unnecessarily.

The same criteria affect these functions as do the major activities. They are discussed in this section in the order in which they normally take place in an operation.

4.1 Felling and crosscutting

Although it would be difficult to get statistics it is probably true to say that most of the world's industrial timber is felled by means of chain (power) saws. Hand felling is still in use, especially for farmwood and firewood, although axes are wasteful and this becomes a serious matter where there is a

deficit of wood. In highly industrialized countries, where labour costs are steep, there is a noticeable move toward felling with feller-bunchers, sophisticated machines on which research for improvement is continuing.

Chainsaws are simple and relatively cheap little machines which are easily serviced by the operator. Nevertheless, they are high-production machines and have increased workers' output many times over the manual axe/saw methods. Because they are fast they can also lead to unsafe ways of working. In addition to picking the correct saw (power, blade length and safety and ergonomic features), fellers should be given careful training on their use and proper felling techniques.

If workers have been trained, in addition to increasing safety, the manner in which trees are felled can make extraction easier, thus lowering extraction cycle time. It does not take many broken trees of a valuable species to make a logger wish his fellers had been trained.

Productivity in felling is also affected by terrain and weather. The size of the tree may cause a feller to work longer on one tree but if the height is good he will make up in volume or productivity.

There are innumerable brands of chainsaw; suffice it to say that the market is big and competition among manufacturers ensures that they produce a good product. Most have a large research and development staff to see that they put out even better ones in the future.

Associated with felling are the supposedly still more minor items such as clothing (helmets), hand tools, files and repair tools and jacks, to name a few. Although these may seem minor they are essential.

In addition to felling and crosscutting there are two operations which are usually directly related to the former and often carried out at the site by the fellers.

4.1.1 Delimbing

Delimbing is an important part of the shaping of the final product and often one of the most expensive or cost-producing phases of the felling/conversion process. In some temperate forests the expense of delimbing is so great that the basic felling system has been mechanized (with feller/bunchers, processors, flails on skidders). In general, though, delimbing is still carried out by chainsaw, saw and axe.

4.1.2 Debarking (barking)

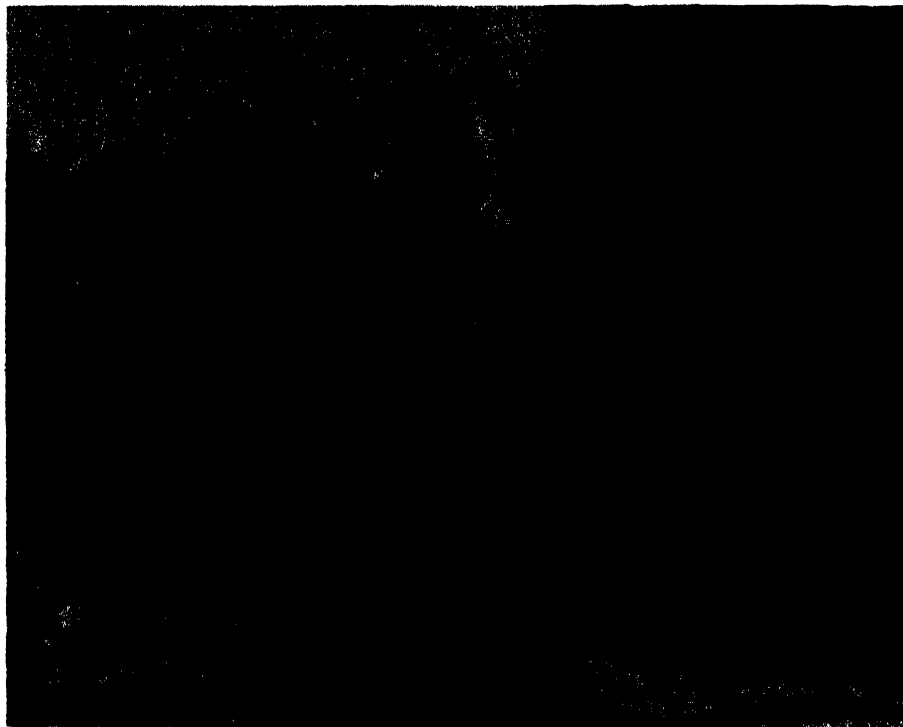
Where logs need to be debarked before entering a mill or being prepared for export, or to prevent infestation or adhesion, they are still often debarked manually in the forest or at the landing. Many, however, go through the process at the mill yard or water landing.

A logger must decide whether to do this in the field, manually, or let the miller do it either manually or mechanically at the mill. The logger's main concern is labour availability and whether or not the weight of the bark will affect the load size which he can haul. He must also be reimbursed for his work. Tools such as barking spuds are simple and readily available.

In some areas debarking is carried out mechanically at the landing by processors which also delimb, crosscut and stack.

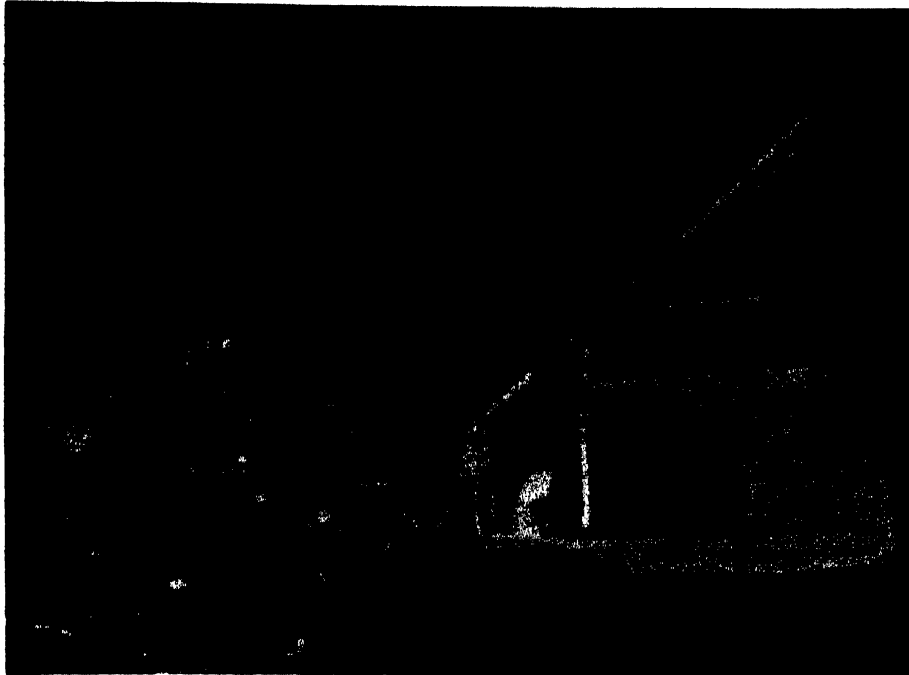
4.2 Loading

Loading normally entails the loading of logs at a forest landing on to a truck, but it can also be required for rail and barge hauls and may be carried out at the stump. Rail and barge loading does not generally involve the same urgency to mesh in with other functions such as extraction and hauling, since these two transport modes are usually fed from a stockpile as and when the wagons and barges are ready. When barges and wagons are available, however, the loading process must be fast and efficient.



Logs loaded on to trucks by a hydraulic crane attached behind the cabin. With appropriate positioning two trucks could be loaded by one crane (Border Timbers Ltd.) (Photo: H. Seppänen)

In truck hauling the most difficult piece of equipment to fit into the overall scheme is usually the loader. This is especially so in small operations where the logs are big, because the large piece of equipment needed to load them is over-productive and would be under-utilized. Many small operators do without and devise makeshift systems or use self-loading trucks. Most of these systems are slow compared with mechanized loaders and tie up the truck for long periods, thus expensive, powerful trucks also become redundant. Similarly, under-productive loaders hold up trucks, thus raising hauling costs.



Loading logs on to a truck with a locally-manufactured truck-mounted cable-crane using a double-drum winch set from a crawler tractor. Logs were transported by a Sisu truck with trailer carrying capacity of about 17 m³ (Forestry Commission, Erin Estate)
(Photo: H. Seppänen)

Loaders are now mostly mobile. Boom loading in cable operations is still practised but its use is declining. Mobile loaders can be said to be front-end loaders mounted on wheels (rubber) or tracks; heel-boom hydraulic loaders also on wheels or tracks; and hydraulic knuckle-boom grapples used for loading smaller trees or logs and pulpwood, which can be mounted on anything from the hauling truck to a farm tractor.

Mechanical loaders have varying degrees of sophistication and the large-log loaders are costly. Big heel-boom hydraulic loaders can cost about US\$550,000, so they must be productive. To be productive they must be where the logs are and usually to be where the logs are they must be mobile.

The decision as to size of the loader depends on the size of logs, which has been decided in the extraction and/or transport phase or by mill requirements. The choice of a wheel- or track-mounted machine depends on how mobile it must be, essentially how far it must travel between loading points, and what the soil and water conditions are in which the machine must move. For some special loaders adaptation to a rubber-wheeled mount can raise the cost considerably, even in the order of 40% above that of a track-mounted model, so the correct decision should be made in the first place. Mobility allows the machines to move quickly between landings as logs are available, thus speeding the truck on its way. Front-end loaders mounted on rubber cannot always function on wet, soft landings - they soon slip, slide and bog down. Track-mounted machines move more slowly and their weight is better distributed, thus they do not churn up the landing so much and are not quite so vulnerable to soil and rain conditions.

Thus, for certain soil conditions a track-mounted heel-boom loader (with rubber tracks if the road is wide enough), loading from logs piled (windrowed) beside the road is sometimes the best solution. This entails being able to place the extracted logs in windrows. A clear-felled forest being logged with a portable skyline system lends itself well to this loading unit. Ground skidding in a selection system could also use this method and thus prevent the clearing of large areas for landings and the resultant extreme disturbance and compaction of the soil.

On some big operations where loading time is a significant part of the total available time of a truck, some operators preload trailers and thus the truck or tractor, which is the expensive part of the unit, is moving more or less continuously. Preloading must be foreseen to give much faster haul times than with normal loading in order to make the extra investment pay. Preloading also requires more space and better landings than those required for direct loading.

One of the commonest mistakes made by the planners for integrated industries is to ignore the logging side of things, because the investment is usually the smallest item of the venture. This brings up many problems as the operation starts, usually reflected in mismatched equipment, especially in an intermediate phase such as loading where only a few units are needed relative to other items.

Rail and barge loading usually require special loading points. The loading equipment or method chosen depends on the facilities provided. A key factor is to be able to manoeuvre the logs so that they take the least space in the barge or wagon. Some railway companies charge by the wagon with weight limits, and naturally according to distance, so a logger must ensure that he loads the maximum allowable. The same principle applies to barges.

Because loading is such a critical function for which to select equipment, spare capacity in marginal situations should be allowed for. This could possibly entail the cost of another machine standing idle for most of the time. One solution is to try to order compatible log unloading and gravel loading equipment which can be brought into play as required.

4.3 Unloading

As in loading, the object is to get the truck back on the road as fast as possible. Often the mill takes over this function and the logger loses control of his truck. If the mill employees are not conscientious, this can be costly.

Logs are unloaded by a myriad of methods and systems, and a logger has to find the cheapest one which will also ensure that his truck is not held up unduly. Essentially the same mechanical methods used in loading are available. The front end rubber-mounted loader appears to be the favourite. Log yards are surfaced and/or compacted and soil conditions do not usually affect this operation as much as they do loading in the forest.

An integrated operation can buy unloading equipment which will unload trucks, sort the logs for size and species, stockpile them and feed the mill. Thus the cost of the machine to the logging operation can be minimal. Big yard machines, which can often lift a whole load, are costly; ones capable of lifting 35 to 55 tons cost in the order of US\$425,000 to US\$555,000, plus shipping costs, duty, etc.

Loggers delivering to water can employ A-frame unloaders which are cheap and efficient, provided the truck is suited, but sinkers, which are common in tropical forests, may prevent this. Some operators use A-frames or parbuckle their logs on the ground, get the truck back on the road and move the deposited logs with a small front-end loader.

4.4 Overhead equipment

This heading covers all non-producing equipment. Although listed with the production functions, it is so important that it has been included here. The numbers and pieces of this equipment are large and their prices are usually relatively smaller than production items; but no operation can function without some or all of them. They form a part of any system.

For instance, an operation cannot be supervised properly without a supervisor and he must have transport. Similarly, the crews must get to and from the job. The state of the roads and the job to be done dictate the type of truck required, for example, four-wheel drive or two-wheel drive.

On large scattered operations and long truck hauls a radio dispatch system can pay for itself in no time. A mobile workshop will reduce machine down-time on any operation.

The logger must ensure that equipment suppliers provide good maintenance and spare parts service. Similarly he must have a good repair depot. Shop equipment is a must and can run into a considerable sum when the cost of all the bits and pieces is added up. The essential, most often needed, spare parts must be stocked and when equipment is ordered for the first time the cost of initial spare parts, tyres, etc., must be included.

And since he wants cost control on his operation, and on each piece of equipment and its major components (tyres, wire rope), he needs an office and the equipment to go with it, like power (plant), telephone and office equipment. Housing and other such infrastructure can add up to a lot of money.

5. INDIVIDUAL CONSIDERATIONS

Once the choice of the system has been made, the choice of the equipment has almost been made. The only problem confronting the operator now is which individual machine fits his particular terrain, weather and forest conditions. The decision will ultimately be up to him and his team.

Skidders generally come in three sizes within narrow limits and crawler tractors suitable for logging in about five. The selection of individuals entails a productivity analysis based on drawbar pull and relevant speed of each machine as given by the manufacturers, and the load the logger expects to pull. It will be obvious in some cases that certain machines are not suitable; for instance, a 55-kW tractor would not be much use in logging large tropical trees whereas a 225-kW tractor would be out of place in a pulpwood stand. A careful look must be taken, however, when tractors are in or near the same range. In tropical forests some loggers maintain that a 100-kW tractor will do the job while others claim they need a 130- to 150-kW machine. Different soil and terrain conditions plus the length of log, plus the logger's philosophy of logging, high speed or low speed, are generally the critical factors.

In the case of cable systems the analysis is based on cycle time or turn time related to productivity, as for ground skidding methods. In cable logging, non-productive time such as changing roads and settings is a major factor which must of course be included in productivity/unit cost calculations.

The logger operating in one forest can make direct comparisons between machines manufactured by the same company, since the forest condition inputs will be the same. Productivity is not enough - this must be merged with machine operating cost to give a unit cost. When estimates are made, the lowest unit cost machine should be the winner, but it should be remembered that if a smaller machine is overworked its down-time might be higher than allowed for in the estimates or it might wear out faster. Marginal unit cost differences can be misleading at times.

Comparison of two machines of the same approximate size and power brings a different input, reliability, into a calculation. This can generally be found out only by experience and comparison with other operators.

Comparison of two different machines designed to do the same job is a particular problem when the logger has no operating experience behind him. He can take the word or advice of the dealer or he can try to find research and study papers (especially on new types of units), but getting around and talking to other operators and owners is one of the better methods. If an operator continues to use a certain type of machine and is still in business he is probably satisfied with his equipment. A word of caution: some people buy on price alone because of their particular financial circumstances and they do not always buy the most suitable equipment. Also, another person's operating philosophy may be different as regards high speed-low speed, longer write-off periods and the like.

A similar selecting process can be carried out to determine the ratio of skidders to crawlers, once the basic size selection has been made. It can be said that crawlers are slower than skidders, therefore the crawler should log the closer areas and the skidders the farthest. The distance at which the productivity of both machines is approximately equal can be calculated.

When it comes to size and configuration of trucks and extraction equipment, the size or length of log becomes very important in the selection process, over and above terrain and road conditions and other restrictions. For instance, a peeler log is usually of much higher value than a sawlog and can be short. Logs for plywood and for sawing require to be cut to specific lengths, with trim, to meet mill specifications. It is difficult to train the feller/bucker to crosscut his logs to the correct length and still get the most value out of a high-quality tree. Sometimes the lie of the tree prevents bucking for quality. In order to overcome this, some operators extract tree length and even haul tree length to the mill, so that the tree can be crosscut under close supervision. It is easy to see what effect this factor has on the choice of size and configuration. Perhaps a 225-kW tractor is needed and perhaps a type of trailer truck with extendible reach (pole).

Nothing beats actual productivity and cost figures. Every new operator should, if his operation is large enough, hire both a cost accountant and a mechanical superintendent. These two should set up a cost accounting system, complete with individual machine costing. The foremen should be trained to understand phase costs and be able to make good suggestions before the old equipment wears out and it is time to replace it, possibly with something else.

The logger has a job to work his way through all that is required to cost each machine. A lot of data are needed; to name a few not yet mentioned in this paper: fuel, lubricants, tyres, spare parts (the amount of each to be used and the cost), labour rates and fringe benefits, depreciation periods, insurance, interest, resale value and so on and so on.

A new venture in a developing country should not try untested, undeveloped systems or equipment unless it has no other choice. What works in a developed country, probably in temperate forests with different criteria and conditions, may not work in a developing country. Too many factors are involved to pick more or less blindly from a large assortment and risk having the venture fail.

Mechanized logging has been going on in the tropics and other forests for a long time and there are many proven systems and pieces of equipment readily available. When it comes to investigating service and spare parts it is a good idea to observe which manufacturer or dealer has the most machines out working in the forest. I have known an area where almost every skidder that is manufactured was to be seen but many were lying idle: when a dealer sells only a single machine he cannot afford to supply much service and a big stock of spare parts. In another area one machine dominated all the others and the dealer's service was excellent. When a logger has a machine standing idle for lack of spare parts it does not take long for him to realize that he should have bought from a company with a reliable spare-parts service. Service is one of the most important factors to be considered when the final selection is made.

The mechanical capability of his personnel or the people in his area may influence a logger's choice of high, medium or low mechanization. His expertise in all the preparatory phases such as road layout and construction, to name one, must be considered when he selects systems or equipment.

Fixed costs have a direct relationship to the amount of time worked and thus productivity. Some machines are susceptible to poor soil conditions and therefore may stand idle, piling the fixed costs. In such a situation either another type of machine must be found which may extend the working period or the existing machine must be modified, perhaps with chains or low ground pressure tracks. If all else fails double shifting may bring the operational hours up to first expectations. Many operations now load and truck in two shifts, thus cutting original capital layout and lowering fixed costs. In some areas they even log under floodlights to keep expensive machines producing, and manufacturers are producing special logging floodlight units.

Wear and tear is a factor to be thought of when equipment is ordered. It can be intensified through the soil and adverse weather conditions prevalent in an area. For instance, crawler tracks normally need turning at about 2 500 hours and a complete rebuild is needed at some 4 000 hours. This could change drastically for the worse if the machine is working in sandy soils. Similarly truck tyres will wear out much faster on laterite and crushed hard rock than on sand or clay. Overloading trucks can seriously shorten their useful life.

To sum up the importance of planning and training in the selection of a system and logging equipment: a system implies a planned method of logging. Therefore planning an operation is the key to its success or failure. In order to have the best chances of success, trained, qualified people must plan an operation from the first, not halfway through it when corrective action will come too late. People become qualified through training, either experience and on-the-job training, or formal training supplemented by experience.

If training is not available an effort must be made to get an appropriate programme started as soon as possible, for there is a lag between the completion of training and making it of some use through experience. Training covers the whole range from the simplest to the upper levels of academia and should be recognized as an essential, even a part of the overall operation, as well as vital for individual phases of machine operation and operating techniques (e.g., felling).

An operation which starts from poor or incorrect planning through to faulty selection of equipment, followed by the use of untrained operational personnel, will have less chance of becoming profitable than a well-planned one, and often it cannot be turned around because of built-in problems that cannot be eradicated without closing the operation.

Above all, the logger must remember that logging is only one phase of the forest industry, which covers the field from seedling to market. He must not build a mill, then ask if there are any trees and what they will cost at the mill gate.

Many countries have neither the necessary logging expertise nor facilities to train people in the requisite skills. FAO has a considerable amount of expertise to draw upon and its primary task is to help Member Nations to the maximum. For assistance, they should not hesitate to contact the appropriate division in the Forestry Department of FAO in Rome, especially the Forest Industries Division.

The great emphasis that the Finnish Government places on training is shown by this course sponsored through their Forestry Training Programme. The Finnish Government is to be commended for its efforts and implementation of so many action training programmes throughout the world.

APPROPRIATE WOOD HARVESTING OPERATIONS IN PLANTATION FOREST IN DEVELOPING COUNTRIES

by

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1. INTRODUCTION

In many developing countries forest areas are rapidly diminishing because of an ever-increasing population, demanding more land on which to grow food. In some dry-zone countries, destruction of the forest has reached a stage leading to reduced fertility of the soil and thus to a considerable decrease in food production.

It is estimated that in the tropical forestry zone alone, in the early nineteen eighties some 7.5 million ha of forests were converted annually into agricultural land.

Because of the rapid decrease of forest resources in some countries there are serious shortages of wood for local use (fuelwood and housing). More and more frequently people have to go farther away to find the wood they need so badly.

Although afforestation efforts have increased over the last decade - it is estimated that some one million hectares are afforested every year in developing countries - they still fall much behind the yearly deforestation rate.

Recognizing the need for increased production of fuelwood, charcoal and construction wood as well as processed wood products to satisfy the local people in developing countries, several forestry departments have launched large-scale afforestation or reforestation programmes.

In a number of countries government forestry administrations have carried out campaigns to promote people's participation, especially at the village and community level, in the afforestation of degraded areas to protect the fertility of the soil and to improve the wood fibre situation. Yet more needs to be done to counterbalance the present rate of deforestation.

Recognizing the seriousness and magnitude of the problem, FAO recently launched an action plan for forests. This should serve as a guideline for concerted and harmonized action of governments and international organizations to promote the development and rational utilization of tropical forest resources. In this Tropical Forestry Action Plan the following five priority areas were established: forestry and land use, forest-based industrial development, fuelwood and energy, conservation of tropical forest ecosystems, and institutions.

In a number of countries rural development schemes combined with appropriate forest management have been promoted by governments in order to stabilize rural population. These schemes will undoubtedly play an important role in alleviating poverty and forest destruction.

2. WOOD HARVESTING, A SOURCE OF DEVELOPMENT

Wood harvesting can be considered as the link between the forest resource base and the industry. It therefore plays a vital role in their development.

Often it has been assumed that wood harvesting is a simple process and therefore does not require any special attention as long as there is an ample forest resource within a reasonable distance from the industries.

Yet in both developed and developing countries there are many examples of forest industries which have failed or are seriously limited in their operations, lacking the necessary raw material supply on a sustained basis, because this assumption had been made.

It should be noted that harvesting represents a major item in the cost of wood products. And apart from economic viability, careful attention should be given to developing relevant and appropriate harvesting systems which are also environmentally and socially acceptable.

Properly used forests will create increased wealth of a country's forest resource base and stimulate the development of forest industries which in turn can improve other sectors of the economy. This will result in better employment possibilities as well as an increase of goods and thus will improve the living conditions of the population. In fact, in countries such as Finland, Sweden and Canada, development of forests and forest industries has played and still plays a significant role in the overall development of the country.

Another important aspect is that proper use of the forest resource comprises not only the utilization of wood but also the production of a full range of products as well as service functions. For instance, non-wood products such as food and fodder could be as important as wood products or even more so to rural people. For example, in mangrove forests sea food is a significant source of income and food for the local people. Other important forest products for rural people may be meat from game, honey, mushrooms, berries, medicinal plants, resins, gums, flowers and ornamental plants, tannin, rattan and bamboo.

Therefore utilization of the forest should be approached holistically, taking into consideration all the production, protection and social functions and bearing in mind improvement of the living conditions of rural people as a whole, rather than those of only a few.

Employment in wood harvesting is especially important for landless people who are often among the poorest members of a rural society.

2.1 Concept of appropriate wood harvesting

A wood harvesting operation can be regarded as appropriate if all the various needs and possibilities have been taken into consideration and if its actions to produce wood are not detrimental to other users of the forest.

A balanced approach will make wise use of the forest resources, taking into consideration the forest's production, protection and social functions.

The right harvesting systems and techniques need to be applied to minimize damage to the trees, soil and terrain, reduce waste of wood, provide a product of good quality, generate employment and income for local people, and permit the utilization of other products and services which are considered important for the development and benefit of the society as a whole.

In some instances, industrial investors have overexploited the forests, ignoring their social and protective functions. In other cases foresters have been too conservation-minded, not making as full use of the resource as would be desirable. In both cases, the utilization is not appropriate.

2.2 Choice of technology

Many different wood harvesting systems have evolved in various parts of the world, ranging from basic logging technology to highly mechanized systems. While industrialized countries require high mechanization because of high labour costs and the frequent scarcity of labour in remote areas adjacent to the forest operations, in developing countries labour-intensive techniques should be applied whenever social, forest and resource conditions permit.

There are many reasons for this. First of all there is generally plenty of labour available at low cost; secondly, because of the shortage of foreign currency it is difficult to buy modern harvesting equipment, which is produced mainly in industrialized countries. Besides, most developing countries suffer from a shortage of skilled operators and technicians to maintain such machinery.

In the past, people often believed that by introducing advanced machinery they could easily overcome the low labour productivity due to fatigue and diet deficiencies, and so ensure a sustained level of raw material supply from forest stand to forest industries. Such action was not only responsible for displacing workers, it was also often counterproductive in the sense that dependency of the developing countries on the industrialized ones increased and operations were curtailed or at worst had to be closed down because of all sorts of shortages and economic and logistic reasons.

Therefore, great attention must be given to the appropriate transfer of technology and the adaptation of logging systems to a specific society and forestry and terrain conditions.

In developing countries, it may often be more sensible to upgrade existing technology, improve work organization and apply proper safety concepts, thus reducing accidents and risks to health. It may be advantageous only at a later stage gradually to introduce a higher technology.

In principle, one can differentiate among three major levels in forest harvesting technology: basic, intermediate and highly mechanized.

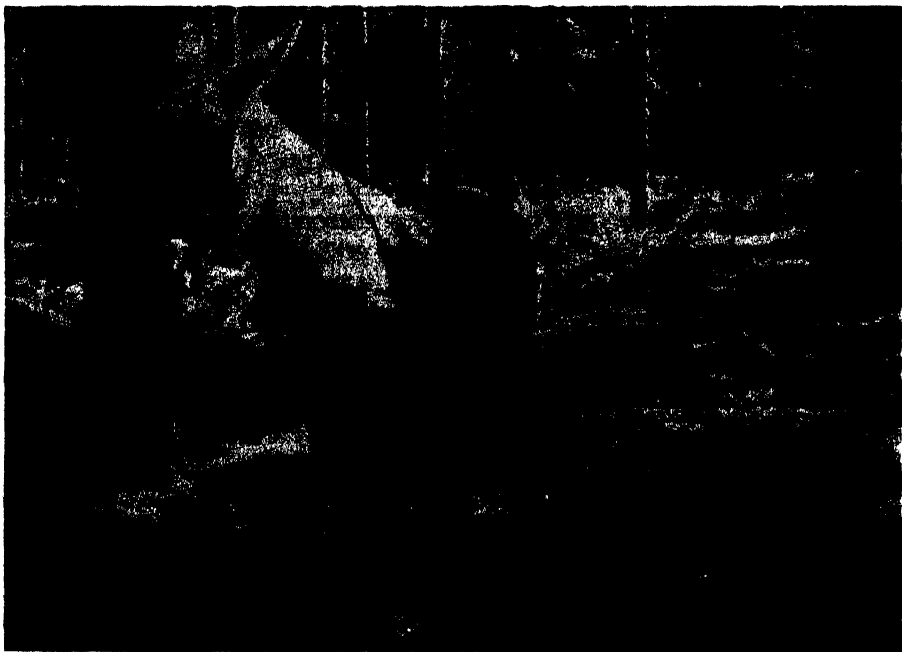
2.2.1 Basic wood harvesting technology

In operations falling under this heading the labour input is predominant. Through use of good handtools and simple equipment remarkable results can be achieved in improving the productivity of traditional labour-intensive logging methods. Handtools and equipment are relatively cheap and can be easily manufactured using local skills and materials. Through the provision of these modest tools and equipment the logger will be able to work more efficiently and increase his output while expending less energy.

This will not only lead to a more efficient operation, but also improve safety in the work performed and finally result in increased earnings. Equal in importance to the use of improved tools and equipment is their proper maintenance if they are to continue to serve the purpose for which they were designed.



The mule has the advantage of being able
to work on steeper terrain than oxen and
is also more resistant to diseases
- but is more difficult to train
(Border Timbers Ltd.)(Photo: H. Seppänen)



A single mule is able to skid an average of 7 m³
a day over a distance of 30 m
(Border Timbers Ltd.)(Photo: H. Seppänen)

Use of basic logging technology promotes employment and is therefore of direct benefit to the worker. After he is acquainted with the technology it should be considered as a tool to further development, until more sophisticated equipment and systems are finally reached.

Although in almost all industrialized countries manual saws and axes have been replaced by chainsaws in felling operations, in developing countries the use of axes and handsaws is still a valid option which, with high-quality steel, can give good results. In a number of developing countries manual felling methods prevail when small to medium-sized trees are cut in plantation forests. For instance, studies on the use of hand saws carried out by Sweden in felling operations in India showed that saws with good design and made of high-quality steel double the work output with half of the energy input.

A similar case study was made on two-man peg-tooth crosscut saws and one-man bowsaws, which showed that the latter were nearly twice as efficient as the former.

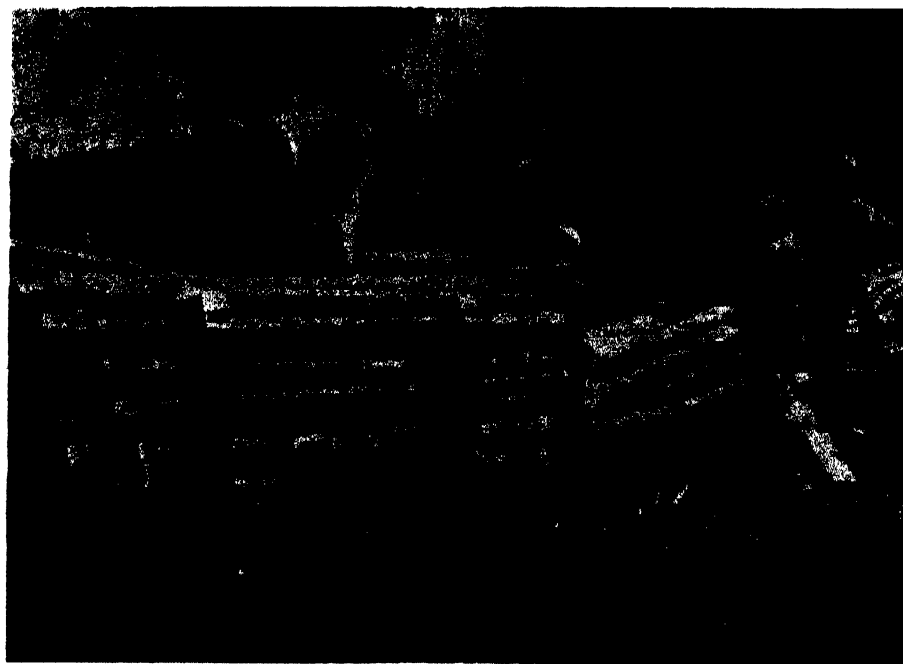
As far as extraction, transport and lifting of logs are concerned, there are still plenty of examples where logs are moved manually by means of animals and simple handtools and equipment developed in various developing countries. In Tanzania in recent years a simple sulky for manual logging has been developed. This has proved to be efficient and considerably reduced the workload of the forest workers.

Special skills have been developed in mountain logging as well as in swamp logging operations. In the mountains there is a long tradition of moving logs by means of gravity, either on the soil or, where the terrain is covered by stones and boulders, by means of log or timber chutes. Even in some industrialized countries, for instance Austria, some 40 percent of the annual wood harvest or 4.5 million m³ are still manually moved downhill, primarily with the help of hookerons or sometimes skid pans and chutes, although labour costs are at least 50 times higher than those in most developing countries.

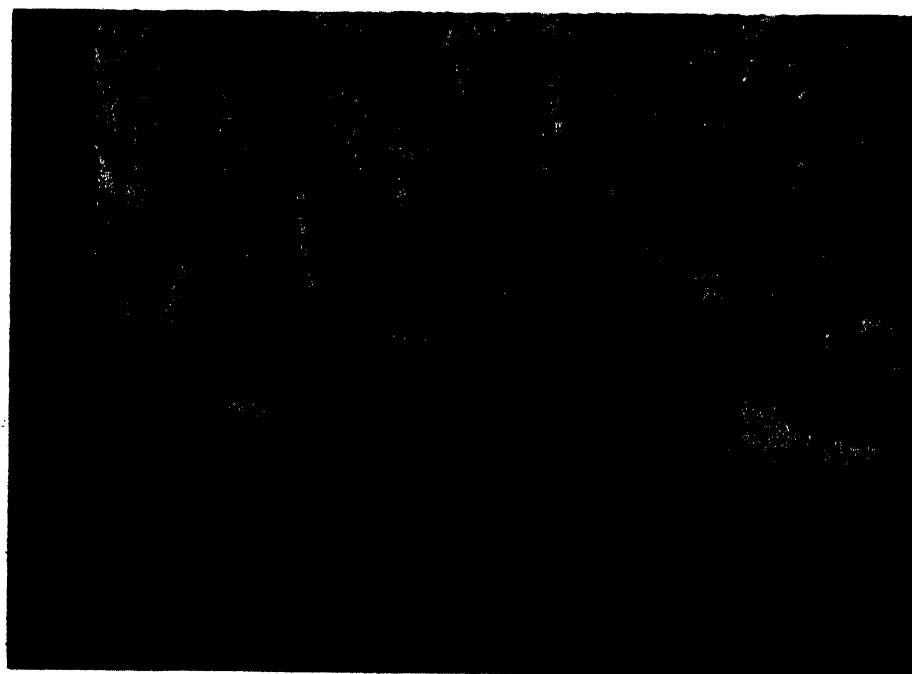
A recent study carried out by FAO's Forest Logging and Transport Branch (FOIL) on mangrove harvesting in the Peninsula of Malaysia revealed that charcoal and firewood billets can be efficiently transported by wheelbarrow. In the operation studied the wheelbarrows were moved on timber tracks over an average distance of 150 m from the felling site to the river or canal. There the billets were loaded on to boats and transported to the charcoal kilns. The wheelbarrows were constructed locally and were equipped with a shoulder strap to lift and keep the barrow in balance. The average load was about 300 kg.

In the past, manual logging in tropical high forest was common in the Far East. In fact, the pulling of logs by a group of men, as in Indonesia where it is called kuda-kuda logging, was widely used; this activity provided employment and income for the local people. With the introduction of modern harvesting machinery in forestry, however, the manual extraction of logs lost its importance.

In some Latin American countries, for instance in the forests of the Pacific coastal region of Colombia, the local population is still involved in manual wood extraction. Generally, single logs are moved manually along prepared skid trails made of logs. In some instances, canals are constructed and at high tide logs are floated to the river or sea for further transport and processing.



Manual loading of an agricultural tractor and trailer by a five-man crew. The transport distance to the intermediate landing was about 5 km (Mutare Board and Paper Mills) (Photo: H. Seppänen)



Manual stacking of pulpwood (Pinus taeda). The wood was felled by bowsaws and extracted manually to the roadside. (Forestry Commission, Erin Estate) (Photo: H. Seppänen)

In several countries, often even though specialized high-productive logging machinery has been introduced, animal power still is used successfully and economically, although productivity is rather low. For example, elephant logging is a well-established technique in natural forests in several Asian countries such as Burma, India, Sri Lanka and Thailand.

In remote areas of hilly and difficult terrain in Burma, some 4,000 elephants are still used today in logging operations. Their daily production varies from 3 m³ to 6 m³, depending on the skidding distance, forest and terrain conditions.

In plantation forests, traditional logging with oxen has been and still is used successfully to a considerable extent in various countries. Some of these are Burma, Chile, India, Malawi, Mexico and Zimbabwe. In some countries buffaloes and horses are used.

In 1984, following a request by Tanzania, FAO fielded a mission to study the possibility of establishing a demonstration and training centre on logging with oxen, which resulted in the formulation of a project proposal.

Similar projects may in the near future materialize in Central America where there is a strong interest in involving the local people in logging using a combination of oxen and light cable systems. For instance, Honduras is interested in studying the possibility of local people's participation in the procurement of raw material for rural communities and forest industries.

In Mexico and Chile, where comparative studies on manual, animal and mechanized log extraction were carried out, it became evident that under the then prevailing conditions, animal skidding, especially for short distances in favourable terrain conditions, was compatible with log extraction by agricultural tractors with forestry attachments.

Similar results were obtained in Malawi where an oxen logging training centre was established in the mid-nineteen seventies and nowadays extraction of sawlogs is carried out successfully in pine plantations. The average skidding production per day per pair of oxen was 4.5 m³ when logs were skidded over a distance of 350 m. In 1979, extraction costs amounted to US\$ 0.55 per cubic metre.

When manual and/or animal systems are selected it can be a difficult and complex task to coordinate and guarantee a continued wood supply to large-scale forest industries because of the involvement of numerous people and animals. Nevertheless, this is successfully used in Chile to supply wood to large-scale pulp and paper companies.

In 1982 ILO undertook a study in the Philippines to promote appropriate forestry technology, which deals among other operations with basic logging techniques using improved handtools and equipment for animal skidding, as well as attachments for farm tractors.

As a follow-up to this study FAO in 1985 commissioned the Forest Research Institute in Laguna to make two case studies on appropriate logging technology. They were carried out in Ipil Ipil plantations supplying wood for energy, to investigate presently applied technology in wood extraction by carabaos (buffaloes) and agricultural tractors and identify the production and cost levels of the systems in use. The object was not so much to improve the harvesting system but to determine the suitability of the applied technology for

maximum involvement of the local people in supplying wood to power plants. The reports on these case studies will give a brief description of the systems examined and their results. They will be accompanied by a colour slide set for each system. These two studies will form part of a series of case studies on appropriate wood harvesting systems.

2.2.2 Intermediate wood harvesting technology

In these operations manual labour is reduced in comparison with basic logging technology, part of it being replaced by machines and equipment which facilitate the work and considerably improve production output per man/day.

Felling with chainsaws

As a consequence of mechanization in forestry work in many countries, axes and handsaws used in felling operations have been substituted by chainsaws. The expected results in improved productivity in terms of output and earnings can, however, be achieved only if proper training is provided at both operational and maintenance levels.

In addition, appropriate back-up (access to spare parts and fuel) is required.

In connection with its forestry field programme, FAO has in the past carried out a number of training courses on chainsaw operations and maintenance.

In cooperation with ILO, the Organization has produced a handbook on chainsaws. The aim of this training manual was to make the use of chainsaws in felling operations easier, safer and more efficient.

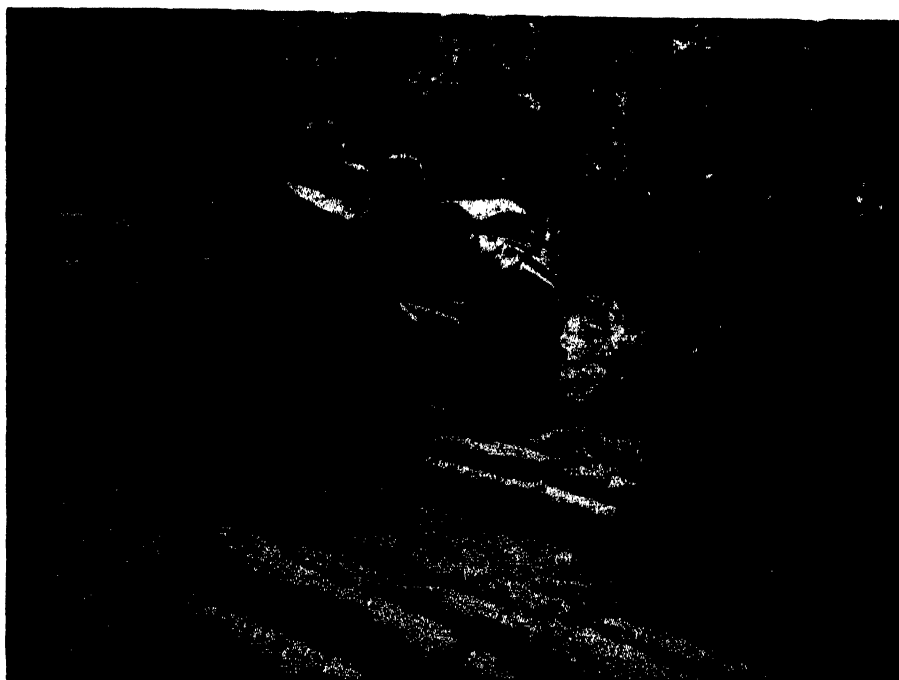
Wood extraction and transport

Agricultural tractor

The agricultural tractor equipped with appropriate forestry attachments may in many cases do a good enough job. Numerous types of forestry attachments exist for various jobs and sizes and models of agricultural tractors. Forestry attachments such as single- and double-drum winches, logging trolleys, cable equipment, semi-trailers, trailers with or without mechanical cranes, are presently in use in many countries.

The factors limiting the introduction of this machinery are often the type of soil and terrain, the size of trees and accessibility. When an agricultural tractor is used in the forest stand for skidding logs downhill, the maximum gradient the machine can negotiate is 25 percent. Although this type of intermediate logging technology is widely used in plantation forests in industrialized countries, it has not yet won the same popularity in developing countries.

Two of the reasons are that sometimes advanced technology has more prestige and it is more aggressively advertised in industrialized countries, factors which undoubtedly influence the decision-making process.



An agricultural tractor used in thinnings of Pinus taeda forests. The average load was 1 m³ (Border Timbers Ltd.) (Photo: H. Seppänen)

One of its chief advantages is that this type of equipment with appropriate attachments can be used for forestry purposes without any major extra investment and will give the farmer a profitable additional use of the tractor. In fact this is one of the reasons why in a number of European countries agricultural tractors by far outnumber the specialized logging machines such as skidders and forwarders. A similar trend to use more agricultural tractors in forestry work has been observed in New Zealand and Australia.

When an agricultural tractor is used in forestry work it should have the following specifications in order to meet the job requirements and safety standards:

- four-wheel drive and roll-over protective structure (either roll-over frame or safety cab);
- three-point linkage (except where forestry attachments are mounted directly on the tractor);
- power take-off;
- bottom safety shield (a pan to protect the engine);
- power source of 35-56 kW.

Tractor-attached winch

Tractor-attached winches are used for ground-lead uphill extraction of logs for distances of 30 to 50 m. The tractor is positioned on the forest road with the winch pointing toward the valley side so that logs can be pulled up from the

slope below the road. Winches can have either a single or double drum and may or may not be equipped with a logging plate. A logging plate is useful to stabilize the tractor, and especially to prevent it from skidding back while pulling in the logs.

There are various types and sizes of winches and of skidding plates. Some winches have drums located parallel to the tractor axles while other drums are perpendicular. Tractor-attached winches generally have a line pull ranging from 1500 Kp to 5000 Kp. Time and work studies were recently carried out in a logging project in southern Viet Nam pine plantations with an agricultural tractor and an attached winch. The studies revealed that in comparison with the traditionally used tracked skidders the newly introduced tractor with winch gave a much higher production, especially when used for ground-level logging. Studies in Mexican pine plantations showed that the production per man/hour when logs were skidded over an average distance of 80 m was 2.60 m³.

Tractor-attached trolley

This tractor attachment is essentially a small trailer with two wheels, a built-in single-drum winch and a skidding plate. Its advantage is that it can be used efficiently both for winching and for skidding on the forest floor as well as on the skid road. When logs are pulled uphill the skidding plate acts as a safety protection structure whereas when the load is skidded, it acts as support for the log, reducing the friction on the floor. A further advantage of this system is that the pulling forces are exerted on the axle of the trolley and not directly on the rear axle of the tractor. The maximum line pull of the winch built into the trolley is 4000 Kp.

A few of these trolleys have been tested in developing countries (Bhutan, Mexico and Sudan) and have shown encouraging results.

Tractor-attached cable equipment

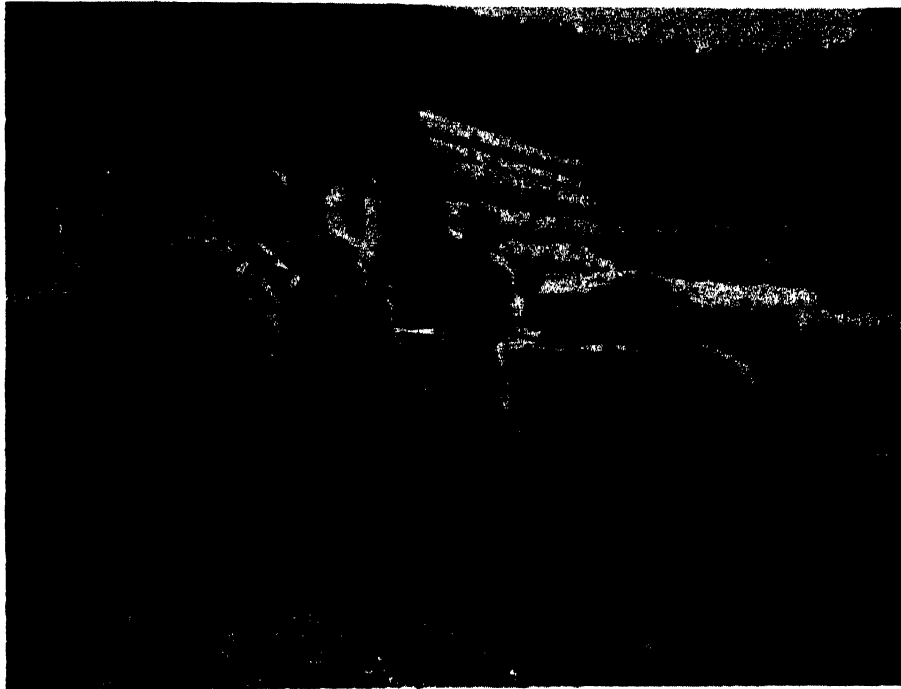
Tractor-attached cable equipment is an ideal supplement in opening up forest resources and utilizing them properly. It prevents damage from transport to the soil and terrain as well as to the remaining stand, and thus provides an environmentally suitable harvesting system on difficult and steep terrain. It requires a good road network as its maximum working range is generally limited to 300-500 m.

This cable equipment is essentially a tower equipped with a mainline drum, a skyline drum and rigging drums, cables as well as a carriage. It is operated as a skyline system and can be used uphill and downhill. Generally, the maximum payload to be transported by this system is not more than 1.5 tons; therefore it can be applied only in plantation forests with relatively smaller trees. In plantations with larger trees, it is suitable for transport of short logs. It can also be efficiently used in thinnings as setting-up time by a well-trained team is not more than two working hours, therefore it does not require large quantities of logs per setting. Because of its high mobility and the small volume of logs required per unit area, this equipment is highly recommendable in order to improve silvicultural work. It should be used essentially on steep and difficult terrain where ground skidding is not feasible or not permitted for environmental reasons.

FAO has assisted in pilot projects to study the use of this simple mobile cable system in several developing countries, for instance, Bhutan, El Salvador and Mexico. The idea was to study machinery demanding low capital investment, using environmentally sound techniques on fragile soils and improving efficiency in forest harvesting operations.

Trailers for log transport

Simple trailers, often made in a local workshop, are an ideal supplement to an agricultural tractor already employed in the extraction phase, for transporting wood over short distances. This type of machine has been designed essentially for farmers and small contractors to carry out the transport of logs from the road to the main logyards or to local forest industries in the vicinity of the forests, or for their own needs.



Unloading an agricultural tractor and trailer combination by releasing the rear stakes and tipping the trailer hydraulically
(Mutare Board and Paper Mills) (Photo: H. Seppänen)

Some have single axles and are equipped with tilting devices which make the unloading of shortwood especially easy. This type is generally used in transporting pulp or firewood and requires logs to be loaded parallel to the trailer axle. Such trailers may have a load capacity which ranges from 2 to 4 m³. Two-axle trailers can be used for transport of both shortwood and logs. Their load capacity can be up to 10 tons.

They often have mechanical cranes mounted on them with a carrying capacity generally below 1 ton.

Traditional skyline cable equipment

In mountain plantation forests with large trees and a low roadnet density, the traditional skyline cable system may be an appropriate method of harvesting logs both selectively and in strip cuttings.

The simplest skyline system which can be recommended for use in mountain logging, especially in plantation forests in developing countries, is the gravity cable system. Here the cable equipment is composed of a single-drum winch stationed at the upper point of the setting, a skyline cable, a mainline and a carriage with or without a built-in stopping device. When this equipment is used, wood can be harvested generally on a cutting area of up to 5 ha, covering a span of up to 1000 m and with a reach on both sides of the skyline of 25 m. For instance, in Bhutan, a single-drum yarder of 50 kW and a 25 mm skyline could transport a fully suspended log load of 2.5 tons. Transport is achieved by gravity. The carriage, connected with the mainline, runs downhill on a tensioned skyline.

Several cable cranes are at present in operation as described above, in temperate broadleaved forests in Bhutan, to supply plywood logs to a veneer factory recently established by an FAO/UNDP technical assistance project. As this cable system carries only a limited payload, short-log transport has to be applied, required in Bhutan in any case because of transport restrictions due to the non-availability of heavy-duty logging trucks and to the narrow winding roads. It has been reported that a daily production of 20-25 m³ is achieved. The cable logging cost amounts to US\$ 5 per cubic metre.

2.2.3 Highly mechanized technology

In most industrialized countries the degree of mechanization in forest harvesting has increased rapidly over the years. Manual/animal harvesting systems were substituted by partly mechanized ones, which again have been replaced by more powerful and specialized machines guaranteeing a more efficient and reliable wood supply. Finally, for favourable terrain, soil and forest conditions, semi-processors and full harvesters have replaced various different types of machines. In the light of the peak stage of development reached by harvesting technology, namely the processor, specialized ground skidding equipment may be considered as a sort of intermediate technology; but as wood processors are used even in many industrialized countries on only a rather modest scale, specialized ground skidding equipment may perhaps be more generally regarded as highly mechanized technology.

When using highly mechanized logging techniques one has to keep it in mind that because of the high capital involvement, good maintenance services are required, as well as special training and skills to guarantee the expected production output and make the system an economically viable proposition. In many industrialized countries, courses have been established to train heavy-duty machine operators both on simulation models and on actual sites, to provide enough trained manpower for forest operations in which specialized machinery is involved.

Specialized ground skidding equipment

A variety of different ground skidding machines, both rubber-tyred and tracked vehicles, has been developed entirely for the purpose of wood extraction.

As they have been developed for this specific purpose, they can be used more efficiently than intermediate harvesting machinery, on terrain ranging from swampy, soft soils to steep slopes with gradients of up to 50 percent. The three most widely used machines in forest industries operations are articulated wheeled skidders, forwarders and tracked skidders.

With the development of specialized machinery the task of ensuring a steady supply of a large quantity of logs to forest industries has been considerably facilitated, often, however, with detrimental effects on the employment and environmental situations. Therefore, in countries where plenty of labour is available and trees can be handled with intermediate equipment it would not be appropriate to select a more efficient machine. Particularly where capital investment is an important consideration, provided the machine can do the job in the targeted forest, basic and intermediate technology should be much preferred.

The size and power of this type of machinery varies considerably. For instance, there are 20-kW skidders which can be efficiently used in thinning operations, whereas for middle-sized/large trees in plantation forests one would require a 65-kW machine and in tropical forests a 130-kW skidder.

Recently, the forwarder has gained popularity in wood extraction because it can pick up individual logs at the felling sites and transport them to the main landing. Forwarders are now equipped with long-range loading cranes to facilitate picking up the logs and reduce the skid trail network. Generally their payload ranges from 5 tons to about 15 tons in stands of medium-sized trees.

Another type of equipment recently introduced on a wider scale is the tracked skidder, which can be used on soft and swampy terrain and for heavy timber. The advantage of this machine is that ground skidding can be extended to areas which previously could not be handled by skidders. As it is a tracked machine the soil pressure is half that of a rubber-tyred machine and its speed is considerably higher than that of the traditional crawler tractor.

On easy to fairly easy terrain, mechanization of large-scale harvesting operations in industrialized countries has recently advanced to such an extent that one machine can carry out several jobs. There are feller-skidders, feller-forwarders, delimer-buckers, feller-delimers, feller-delimer-buckers, etcetera. It is obvious that such machines would not be appropriate in countries where labour is plentiful and salaries are modest.

When new harvesting methods and techniques are introduced, careful thought must be given to whether they are economically feasible and socially, culturally and environmentally acceptable.

3. FAO'S ACTIVITIES IN PROMOTING APPROPRIATE WOOD HARVESTING TECHNOLOGY

As there is a considerable shortage of trained manpower for logging at all levels, the Forest Logging and Transport Branch of FAO will in the forthcoming biennium further concentrate on providing and improving the supply of information and expertise to rural people, logging companies and institutes for education, training and research. The activities aim at raising the level of skills and expertise in logging and thereby at improving efficiency in wood harvesting operations.

In particular the following activities are planned:

3.1 Training

3.1.1 Survey of logging training needs

The Branch has initiated a survey of logging training needs in selected developing countries, which will be carried out during the 1986/87 biennium. This project was made possible by a special contribution from the Finnish Government and is executed jointly by the Forestry Training Programme of Finland (FTP) and FOIL. Its primary object is to gather information on wood harvesting and training presently carried out. On the basis of the information collected, an action programme should be developed and further in-depth studies undertaken to implement specific training activities.

The immediate aims of the project are:

- to provide details of existing training institutions;
- to determine the most urgent needs of forest personnel training in relation to logging operations, both present and future, with regard to forest types, harvested volumes, the methods and equipment used, and manpower requirements;
- to compile and present reports on the information collected to provide a basis for the development of future training activities;
- to make recommendations on present and future training activities, which should assist in providing enough well-trained manpower and lead to improved harvesting operations.

Altogether some 30 countries will be visited and field surveys undertaken in the Africa, Asia/Pacific and Latin America/Caribbean regions.

The results of the survey will be presented in a report on each region. General conclusions and recommendations at country level as well as at the regional level will be given. Examples of good training programmes for each region will be highlighted.

3.1.2 Regional training courses on appropriate wood harvesting operations

This programme is sponsored by the Government of Finland and is executed by FAO in cooperation with Finland's Forestry Training Programme.

A series of three training courses will be carried out, one in each region. The first course was held in 1986 in Zimbabwe for SADC countries and other English-speaking African countries in whose overall development forestry and forest industries development play an important role. A second course will be held in the Far East in November 1987.

The main objectives of the training courses are as follows:

To train log-production managers from developing countries to improve the overall efficiency of wood harvesting operations, taking into consideration the use of technology appropriate to the social, forestry and environmental conditions;

To promote analyses and discussions by the participants to draw conclusions and make recommendations on training needs and improvement of wood harvesting technology, taking into account the employment possibilities in using appropriate technology;

To disseminate lectures, information on country reports and case studies as well as to prepare a technical report, which could be used as reference material to promote improved systems of appropriate technology in the procurement of raw material for forest industries and local needs.

3.1.3 Training course on mountain forest harvesting

Provided contributions are received from a donor country, FOIL intends to continue the series of training courses on mountain forest operations with special consideration of and emphasis on protection and preservation issues. The aim of the course is to exchange views and information on newly developed techniques orientated toward people's participation.

3.2 Case studies on basic and intermediate logging technology

During the 1986/87 biennium the Forest Logging and Transport Branch will continue with the above-mentioned programme in which various case studies will be carried out to evaluate the suitability of different alternatives of wood harvesting techniques under certain conditions. The results will be disseminated.

For each case study, a report will be prepared accompanied by a slide set to complement the technical information and assist forestry production officers in their training efforts.

During this period an Andre Mayer fellowship study will also be carried out to investigate logging techniques allowing strong participation by local people.

3.3 Programme on reduction of wood losses

One of the important programmes for the 1986/87 biennium is the promotion of fuller use of the forest resource base in the tropics, and the reduction of wood losses, both in the forests and at mill sites. This will include a series of studies on activities such as the utilization of lesser-known species and smaller-dimensioned trees from silvicultural operations, as well as ways to improve harvesting systems in order to reduce harvesting and post-harvest losses.

As a first step, an interregional study will be undertaken to identify the provenance of the residues and determine, among other things, their characteristics and volume.

On the basis of these initial studies further future activities will be drawn up to provide solutions to the under-utilization and wasteful use of forest resources.

Under this programme various studies will investigate the potential uses of special forest products such as coconut and rubber plantation wood.

3.4 Forest logging information system

FAO's newly set up computerized equipment information system contains data on logging, transport and road construction machinery. It is hoped that during this biennium the system will be further improved and expanded to build up a comprehensive data base on manufacturing companies and technical specifications of equipment in order to improve the servicing of member countries.

During the biennium FOIL will develop a computerized forest harvesting production and cost information system which will enable the Branch to provide immediate data on productivity and costs of different logging methods for specific conditions. It will also serve as a source of information for prefeasibility and investment studies. The software developed will be available later on to member countries interested in this field. Production and cost data will be put in from FAO field projects and other sources of information. In addition the system can be used in simulations to determine wood production costs for a given set of input data, and to identify raw-material procurement costs, based on social, forest, terrain and environment conditions.

3.5 Publications and reports

The Forest Logging and Transport Branch has produced a number of reports and publications on wood harvesting, which deal with various logging aspects and issues.

Below are listed a few reports which may be of interest in connection with the transfer of appropriate technology in wood harvesting operations.

LIST OF PUBLICATIONS

FAO 1979	Logging operations: report of the FAO/Norway Training Course, TF-RAS/79(NOR). Rome.
FAO 1979	The training, motivation and social promotion of forest workers. Position paper EEP/14. Eighth World Forestry Congress. Jakarta.
FAO 1979	Mountain forest roads and harvesting. Mountain forest roads. FAO Forestry Paper No. 33. Rome.
FAO 1980	Chainsaws in tropical forests, FAO Training Series No. 2. Rome.
FAO 1982	Appropriate technology in Forestry. Forestry Paper No. 31. Rome.
FAO 1982	Basic technology in forest operations. Forestry Paper No. 36. Rome.
FAO 1984	Proceedings of the First FAO/Finland Workshop on Management of Forest Industries. Rome.
FAO 1984	Extracción de trozas mediante bueyes y tractores agrícolas, Estudio FAO, Montes No. 49. Rome.
FAO 1985	Fourth FAO/Austria training course on mountain forest roads and harvesting. FAO Forestry Paper No. 14, Rev.1. Rome.

COST CONTROL IN LOGGING AND ROAD CONSTRUCTION

by

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1. PRINCIPLES OF COST CONTROL

1.1 Introduction

Cost is of vital importance to all industry. Costs can be divided into two general classes: absolute costs and relative costs. Absolute cost measures the loss in value of assets. Relative cost measures the unfavourable side of any decision that is made. Relative cost always involves a comparison between the chosen course of action and the course of action that was rejected. This cost of the alternative action - the action not taken - is often called the "opportunity cost".

The financial accountant is primarily concerned with the absolute cost. The engineer, the planner, the alert manager needs to be concerned with the alternative cost - the cost of the lost opportunity. Management has to be able to make comparisons between the policy that should be chosen and the policy that should be rejected. Such comparisons require the ability to predict costs, rather than merely record costs.

The data of recorded cost are, of course, essential to the technique of cost prediction. The form in which many cost data are recorded, however, is such that it limits accurate cost prediction to the field of comparable situations only. This limitation of accurate cost prediction may not be serious in industries where the environment of production changes little from month to month or year to year. In logging, however, identical production situations are the exception rather than the rule. Unless the cost data are broken down and recorded as unit costs, and correlated with the factors that control their values, they are of little use in deciding between alternative procedures. In this paper, the approach to the problem of useful cost data is that of identification, isolation and control of the factors affecting costs.

1.2 Basic classification of costs

Costs are divided into two types: variable costs and fixed costs. Variable costs vary per unit of production. For example, they may be the cost per cubic metre of wood yarded, per cubic metre of dirt excavated, and so on. Fixed costs, on the other hand, are incurred only once, and as additional units of production are produced, the unit costs fall. Example of fixed costs would be costs to move in equipment and road access costs.

1.3 Total cost and unit-cost formulae

As logging operations become more complicated and involve both fixed and variable costs, there is usually more than one way to accomplish a given task.

It may be possible to change the quantity of one or both types of cost, and thus to arrive at a minimum total cost. The relationship between volume of production and costs can be expressed mathematically by the following equations:

$$\text{Total cost} = \text{fixed cost} + \text{variable cost} \times \text{output}$$

$$\text{Unit cost} = \frac{\text{fixed cost}}{\text{output}} + \text{variable cost}$$

In symbols using the first letters of the cost elements and N for the output or number of units of production, these simple formulae are:

$$C = F + NV$$

$$UC = F/N + V.$$

1.4 Breakeven analysis

A breakeven analysis determines the point at which one method of accomplishing some task or objective becomes superior to another method. Breakeven analysis is an extremely common and important part of cost control.

One illustration of a breakeven analysis would be to compare two methods of road construction for a road that involves a limited amount of cut-and-fill earthwork. It would be possible to do the earthwork by hand or by bulldozer. If the manual method were adopted, the fixed costs would be low or nonexistent. Payment would be made on a daily basis and would call for direct supervision by a foreman. The cost would be calculated by estimating the time required and multiplying this time by the average wages of the men employed. The men could also be paid on a piecework basis.

Alternatively, the work could be done by a bulldozer which would have to be moved in from another site. Let us assume that the cost of the hand labour would be \$0.60 per cubic metre and the bulldozer would cost \$0.40 per cubic metre and would require \$100 to move in from another site. The move-in cost for the bulldozer is a fixed cost, and is independent of the quantity of the earthwork handled. If the bulldozer is used, no economy will result unless the amount of earthwork is sufficient to carry the fixed cost plus the direct cost of the bulldozer operation.

If, on a set of coordinates, the cost in dollars is plotted on the vertical axis and units of production on the horizontal axis, we can indicate fixed cost for any process by a horizontal line parallel to the x-axis. If variable cost per unit output is constant, then the total cost for any number of units of production will be the sum of the fixed cost and the variable cost multiplied by the number of units of production, or $F + NV$. If the cost data for two processes or methods, one of which has a higher variable cost but lower fixed cost than the other, are plotted on the same graph, the total cost lines will intersect at some point. At this point the levels of production and total cost are the same. This point is known as the breakeven point, since at this level one method is as economic as the other.

In Fig. 1, the breakeven point at which quantity the bulldozer alternative and the manual labour alternative become equal is 500 m'. We could have found this same result algebraically by writing $F + NV = F' + NV'$ where F and V are the fixed and variable costs for the manual method, and F' and V' are the corresponding values for the bulldozer method. Since all values are known except N, we can solve for N using the formula $N = (F' - F) / (V - V')$

$$N = \frac{100 - 0}{0.6 - 0.4} = 500$$

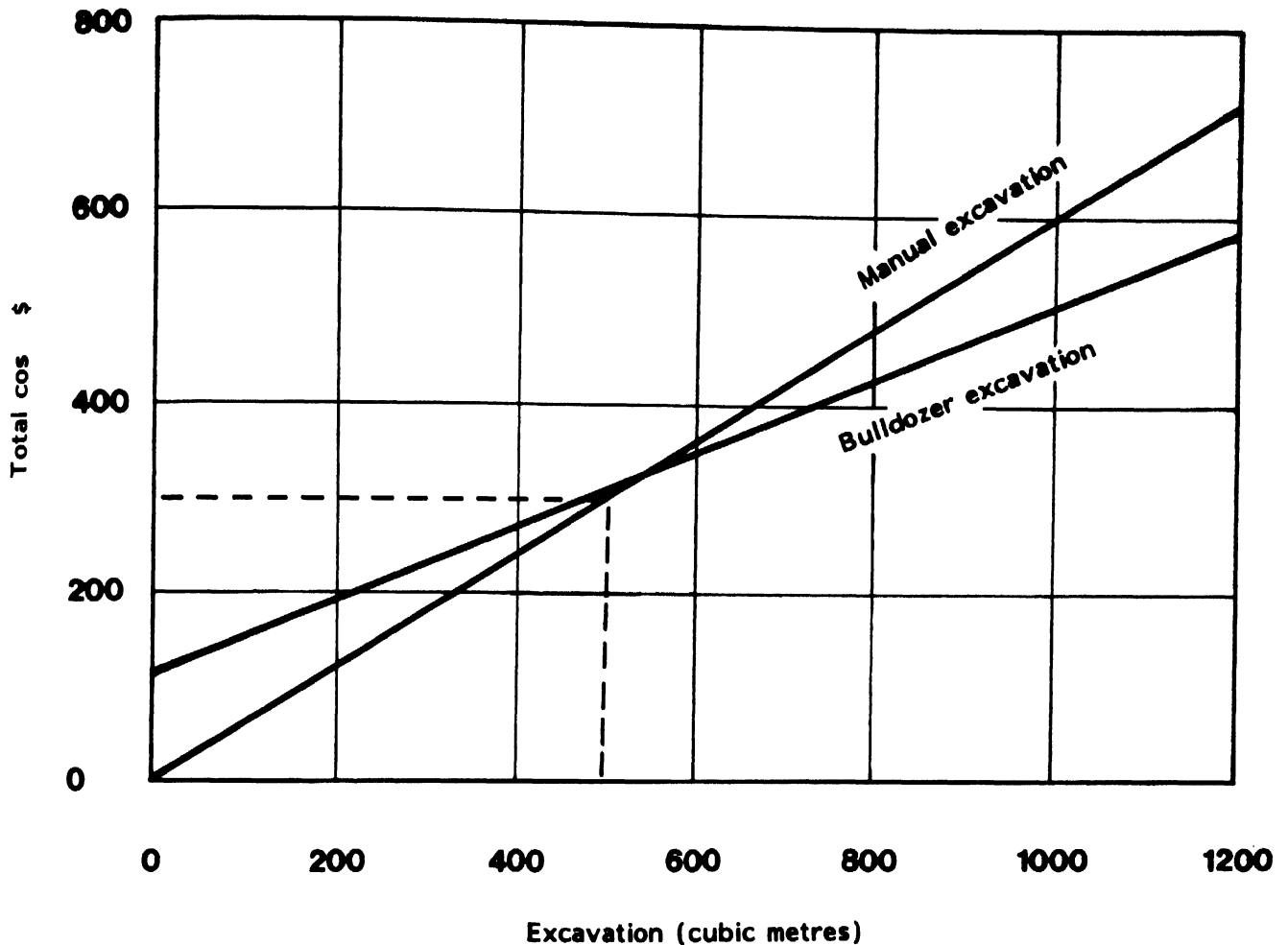


Fig. 1 BREAKEVEN EXAMPLE FOR EXCAVATION

1.5 Minimum cost analyses

A somewhat similar, but different, problem is the determination of the point of minimum total cost. Instead of balancing two methods with different fixed and variable costs, the aim is to bring the sum of two costs to a minimum. We will assume a clearing crew of 20 men is clearing road right of way and the following facts are available:

1. Men are paid at the rate of \$0.40 per hour.
2. Time is measured from the time of leaving camp to the time of return.
3. Total walking time per man is increasing at the rate of 15 minutes a day.
4. The cost to move the camp is \$50.

If the camp is moved each day, no time is lost walking, but the camp cost is \$50 per day. If the camp is not moved, on the second day 15 crew-minutes are lost, or \$2.00. On the third day, the total walking time has increased 30 minutes, the fourth day 45 minutes, and so on. How often should the camp be moved, assuming all other things are equal?

We could derive an algebraic expression using the sum of an arithmetic series if we wanted to solve this problem a number of times, but for demonstration purposes we can simply calculate the average total camp cost. The average total camp cost is the sum of the average daily cost of walking time plus the average daily cost of moving camp. If we moved camp each day, then average daily cost of walking time would be zero and the cost of moving camp would be \$50.00. If we moved the camp every other day, the cost of walking time is \$2.00 lost the second day, or an average of \$1.00 per day. The average daily cost of moving camp is \$50 divided by 2 or \$25.00. The average total camp cost is then \$26.00. If we continued this process for various numbers of days the camp remains in location, we would obtain the results in Table 1.

Table 1

AVERAGE DAILY TOTAL CAMP COST AS THE SUM OF THE COST
OF WALKING TIME PLUS THE COST OF MOVING CAMP

Days camp remained in location	Average daily cost of walking time	Average daily cost of moving camp	Average total camp cost
1	0.00	50.00	50.00
2	1.00	25.00	26.00
3	2.00	16.67	18.67
4	3.00	12.50	15.50
5	4.00	10.00	14.00
6	5.00	8.33	13.33
7	6.00	7.14	13.14
8	7.00	6.25	13.25
9	8.00	5.56	13.56
10	9.00	5.00	14.00

We see the average daily cost of walking time increasing linearly and the average cost of moving camp decreasing as the number of days the camp remains in one location increases. The minimum cost is obtained for leaving the camp in the same location seven days. This minimum cost point should be used only as a guideline, as all other things are rarely equal. An important output of the analysis is the sensitivity of the total cost to deviations from the minimum cost point. In this example, note that the total cost changes slowly between five and ten days. Often, other considerations which may be difficult to quantify will affect the decision.

In the following section where we discuss balancing road costs against skidding costs, a higher road density than would result from the minimum total cost is sometimes selected if excess road construction capacity is available. This is to reduce the risk of disrupting skidding production because of poor weather or equipment availability. Because of the usually flat nature of the total cost curve, the increase in total cost is often small over a considerable range of road densities.

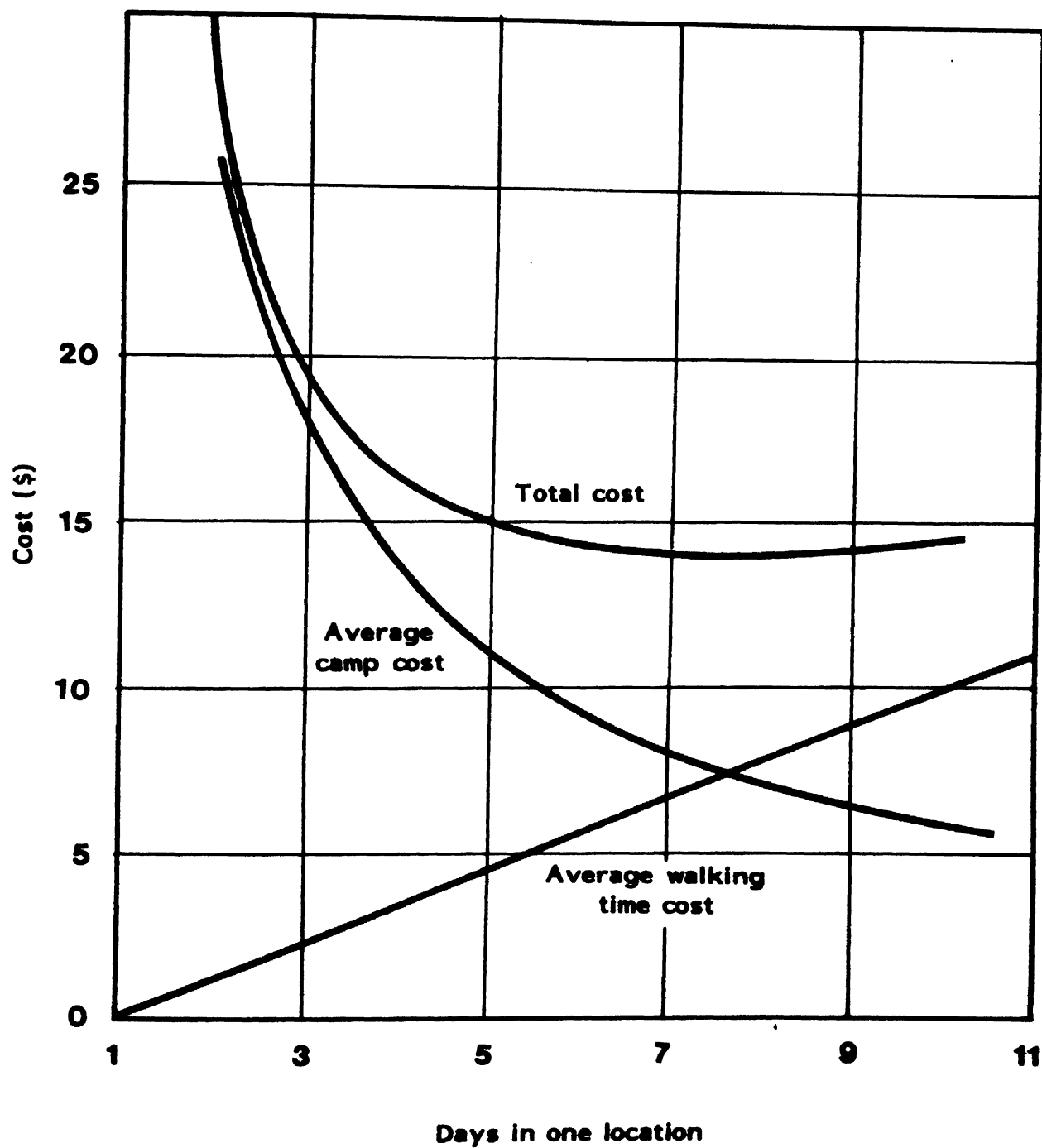
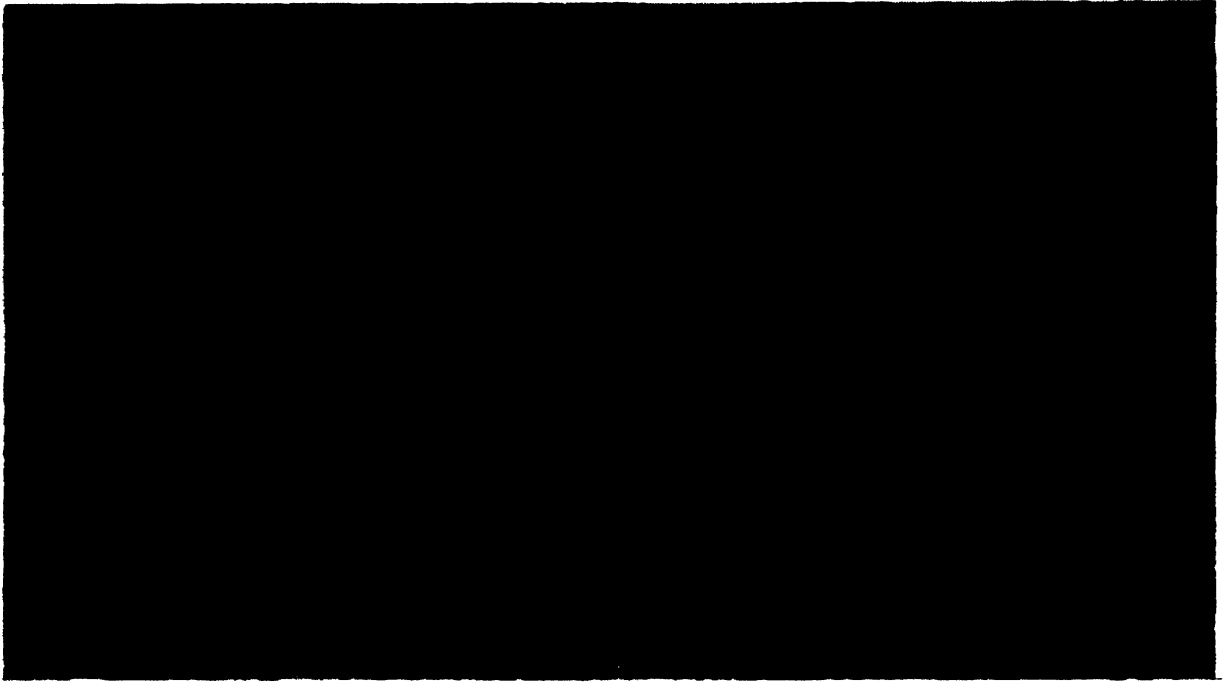


Fig. 2 COSTS FOR CAMP LOCATION PROBLEM



An oxen logging team consisting of three pairs of oxen
and two drivers in a clearfelling operation
in a eucalyptus plantation
(E.C. Meikle Private Ltd.) (Photo: H. Seppänen)



Choking the log in oxen logging carried out
by wrapping the chain around the end of the log
(E.C. Meikle Private Ltd.) (Photo: H. Seppänen)

2. UNIT COSTS AND COST EQUATIONS

2.1 Introduction

The use of breakeven and minimum-cost-point formulae requires the collection of unit costs. Unit costs can be divided into subunits, each of which measures the cost of a certain part of the total. A typical unit cost formula might be:

$$X = a + b + c$$

where X is the cost per unit volume such as dollars per cubic metre and the subunits a, b, c will deal with distance, volume, area or weight. Careful selection of the subunits to express the factors controlling cost is the key to success in all cost studies.

2.2 Example of cost equations

Let us suppose the cost of logging from felling to loading on trucks is being investigated. If X is the cost per cubic metre of wood loaded on the truck, we could represent the total cost per unit as:

$$X = A + B + Q + L$$

where A would be the cost per unit of felling, B the cost of bucking, Q the cost of skidding and L the cost of loading.

To determine the cost per subunit for felling, bucking, skidding and loading, the factors which determine production and cost must be specified. Functional forms for production in road construction and logging are discussed in Sections 4 and 5. Examples for felling and skidding follow.

For felling, tree diameter may be an important explanatory variable. For example, for a given felling method, the time required to fell the tree might be expressed as:

$$T = a + b D^2$$

where T is the time to fell the tree, b is the felling time required per cm of diameter, D is the tree diameter and a represents the felling time not explained by tree diameter - such as for walking between trees. The production rate is equal to the tree volume divided by the time per tree. The unit cost of felling is equal to the cost per hour of the felling operation divided by the hourly production or

$$A = C/P = C/(V/T) = C (a + b D^2)/V$$

where C is the cost per hour for the felling method being used, P is the production per hour, V is the volume per tree, and T is the time per tree. The hourly cost of operation is referred to as the machine rate and is the combined cost of labour and equipment required for production. (Machine rates are discussed in Section 3.)

Example:

Determine the felling unit cost for a 60-cm tree if the cost per hour of a man with power saw is \$5.00, the tree volume is 3 m³ and the time to fell the tree is 3 minutes plus 0.005 times the square of the diameter.

$$\begin{aligned}T &= 3 + .005 (60)(60) = 21 \text{ min} = .35 \text{ hr} \\P &= V/T = 3.0/.35 = 8.57 \text{ m}^3/\text{hr} \\A &= C/P = 5.00/8.57 = \$0.58/\text{m}^3\end{aligned}$$

In skidding, for example, if logs were being skidded directly to a road (Fig. 3), then the distance skidded is an important item and the stump to truck unit cost might be written as:

$$X = A + B + F + C(D/2) + L$$

where the skidding subunit P has been replaced by symbol F representing fixed costs of skidding such as hooking, unhooking and decking and $C(D/2)$ represents that part of the skidding costs that varies with distance. C is the cost of skidding a unit distance such as 1 m and $D/2$ represents the average skidding in similar units.

It is important to note that the average skidding cost occurs at the average skidding distance only when the skidding cost, C, is constant with respect to distance. If C varies with distance as, for example, with animal skidding where the animal can become increasingly tired with distance, the average skidding cost does not occur at the average skidding distance and substantial errors in unit cost calculations can occur if the average skidding distance is used.

Primary road

D = Length of spur road

S = Spacing between spur roads

Fig. 3 TWO-WAY SKIDDING TO CONTINUOUS LANDINGS ALONG SPUR ROADS

If logs were being skidded to a series of secondary roads running into a primary road (Fig. 3), then the expression $C(D/2)$ would be replaced by the expression $C(S/4)$ and the cost of truck haul on the feeder roads would appear as a separate item. In the expression $C(S/4)$, the symbol S represents the spacing of the secondary roads and the distance $S/4$ is the average skidding distance if skidding could take place in both directions. Therefore, the expression $C(S/4)$ would define the variable skidding cost in terms of spacing of the secondary roads.

A formula for the cost of logs on trucks at the primary road under these circumstances would be:

$$X = A + B + F + C(S/4) + L + H(D/2)$$

where $D/2$ is the average hauling distance along the secondary road and H is the variable cost of hauling per unit distance.

The formula can be extended still further to include the cost of the secondary road system by defining the road construction cost per metre, R , and the volume per square metre, V . Then the formula becomes:

$$X = A + B + F + C(S/4) + L + H(D/2) + R/(VS).$$

2.3 Application of cost equations

In the preceding equation, we have a situation where as the spacing between skidding roads increases, skidding unit costs increase, while road unit costs decrease. With the total cost equation, we can look at the cost tradeoffs between skidding distance and road spacing. Calculus can be used to derive the formula for road spacing which minimizes costs, as follows:

$$dX/dS = C/4 - R/(VS^2) = 0$$

or

$$S = (4R/CV)^{.5}$$

An alternative method is to compare total costs for various road spacings. The total cost method has become less laborious with the use of programmable calculators and microcomputers and provides information on the sensitivity of total unit cost to road spacing without having to evaluate the derivative of the cost function.

Example:

Given the following table of unit costs, what is the effect of alternative spur road spacings on total cost of wood delivered to the main road, if 50 m³ per hectare is being cut and the average length of the spur road is 2 km? The cost of spur roads includes landings.

Table 2

TABLE OF COSTS BY ACTIVITY FOR THE ROAD SPACING EXAMPLE

Activity	Unit	Cost
Felling	\$/m ³	0.50
Bucking	\$/m ³	0.20
Skidding	\$/m ³	2.00 (fixed cost)
Skidding	\$/m ³ /km	2.50 (variable cost)
Loading	\$/m ³	0.80
Hauling	\$/m ³ /km	0.15
Roads	\$/km	2000

$$X = A + B + F + C(S/4) + L + H(D/2) + R/(VS)$$

$$X = 0.50 + 0.20 + 2.00 + C(S/4) + 0.80 + .15 (1) + R/(VS)$$

Since only the skidding costs and spur road costs are affected by the road spacing, the total unit cost can be expressed as:

$$X = 3.65 + C(S/4) + R/(VS).$$

To evaluate different road spacings, we vary the spur road spacing S and calculate the total unit costs (Table 3). It is important to use dimensionally consistent units. That is, if the left side of the equation is in \$/m³, the right side of the equation must be in \$/m³. This is most easily done if all volumes, costs and distances are expressed in metres; such as volume cut per m³, skidding cost per m³ per metre, and road cost per metre. For example, the total cost for a spur road spacing of 200 m is:

$$3.65 + (2.5/1000)(200/4) + (2000/1000)/[(50/10000)(200)] \text{ or } \$5.78 \text{ per m}^3.$$

Table 3

TOTAL UNIT COST AS A FUNCTION OF ROAD SPACING

<u>Spur road spacing, m</u>	<u>Total unit cost, \$/m³</u>
200	5.78
400	4.90
600	4.69
800	4.65
1000	4.68
1200	4.73
1400	4.81
1600	4.90
1800	5.00
2000	5.10

The road spacing which minimized total cost could be interpolated from the table or calculated from the formula:

$$S = (4R/CV)^{.5}$$

$$S = \frac{4 \times 2000/1000}{(2.5/1000)(50/10000)}$$

$$S = 800 \text{ m.}$$

When costs have been collected in a form which permits unit costs to be developed from them, not only is it possible to predict costs accurately under given conditions, but it is also possible to adjust conditions so that minimum cost can be achieved. Too often, recorded costs are only "experience figures" and, in the form in which they are usually made available, can be used to predict costs only under conditions that closely conform to those existing where and when the recorded costs were collected. This is not true of unit costs, which can be fitted into the framework of many different logging situations and can be made to tell the story of the future as well as that of the past.

A wide range of cost control formulae can be derived. Typical problems include:

1. The economic location of roads and landings. The calculation of the optimal spacing between spur roads and landings subject to one-way skidding, two-way skidding, skidding on slopes, linear and nonlinear skidding cost functions.
2. The economic service standard for roads. The comparison of the benefits of lower haul costs and road maintenance costs as a function of increased capital expenditures. The calculation of the optimal length of swing roads as a function of the tributary volume.
3. The economic selection of equipment for road systems fixed by topography or other factors. The identification of the breakeven points between alternative skidding methods which have different fixed and variable operating costs.
4. The economic spacing of roads which will be served by two types of skidding machines. For example, machines used to skid sawtimber and to relog for fuelwood.
5. The economic spacing of roads which will be re-used in the future.

Another important application of unit costs is in choosing between alternative logging systems.

Example:

A forest manager is developing an area and is trying to decide between two harvesting plans. He has two choices of skidding systems, two choices of road standards and two choices of trucks. He can buck the bigger logs into smaller logs on the landing. Assume that bucking in the field does not affect log quality or yield.

The manager's staff has developed the relevant unit costs, which are summarized in Tables 4 and 5. What should he do?

Table 4

UNIT COSTS FOR OPTIONS OF USING
SMALL EQUIPMENT AND LARGE EQUIPMENT

	Small equipment (\$/m ³)	Large equipment (\$/m ³)
Felling, bucking	0.70	0.50
Skidding	1.70	2.55
Loading	1.00	0.80
Transport	*	*
Unloading	0.40	0.30
Processing	-	0.05

See Table 5 for transport costs as a function of road standard. Wood for a large system could be bucked on landing for \$0.15/m³ and loaded on small trucks.

Table 5

UNIT COSTS FOR ROAD AND TRANSPORT OPTIONS
USING SMALL AND LARGE EQUIPMENT

	Small equipment \$/m ³	Large equipment \$/m ³
Road		
High std	1.30	1.30
Low std	1.00	1.00
Transport		
High std	3.50	3.00
Low std	4.00	3.40

These choices can be viewed as a network (Fig. 4). We can verify that the cheapest solution is obtained by using the smaller skidding equipment and trucks and constructing the higher-standard road. The total unit cost will be \$8.20 per m³. A key point is the ease with which these problems can be analysed, once the unit costs have been derived. In turn, the derivation of the unit costs is facilitated by having machine rates available.

3. CALCULATION OF MACHINE RATES

3.1 Introduction

The unit cost of logging or road construction is essentially derived by dividing cost by production. In its simplest case, if a tractor with operator is rented for \$60 per hour - including all fuel and other costs - and 100 m³ is excavated per hour, the unit cost for excavation would be \$0.60 per m³. The cost of the tractor with operator is called the machine rate.

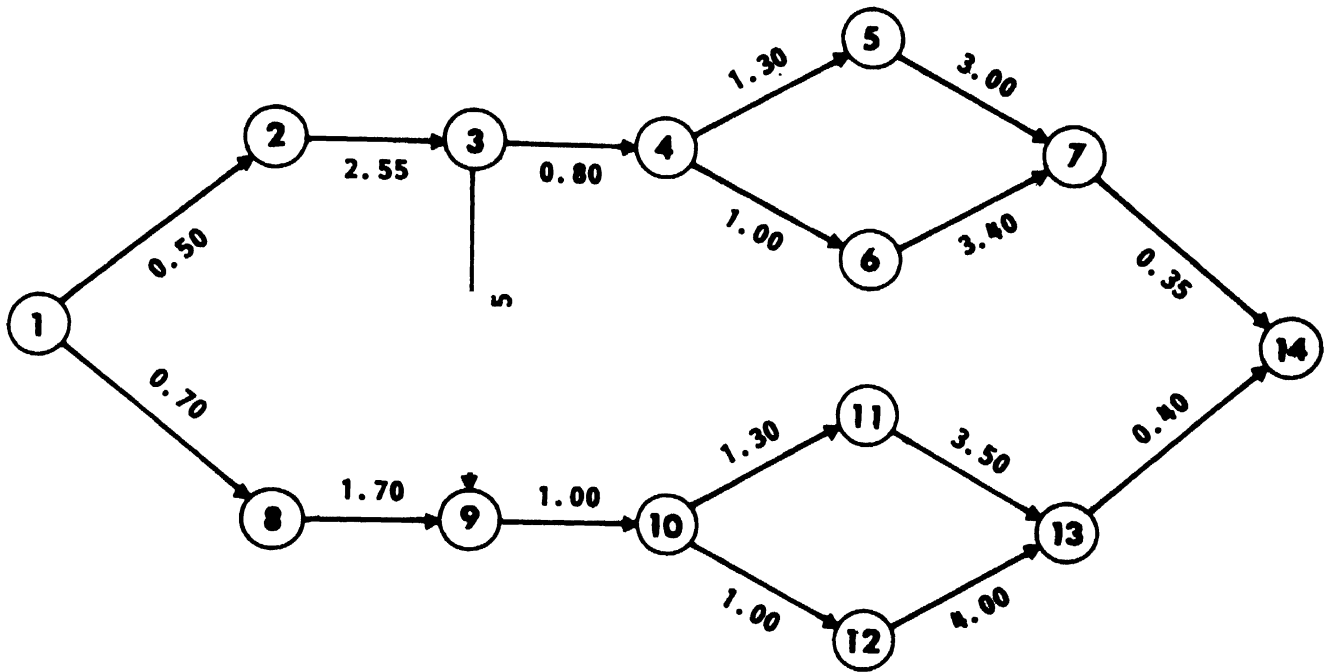
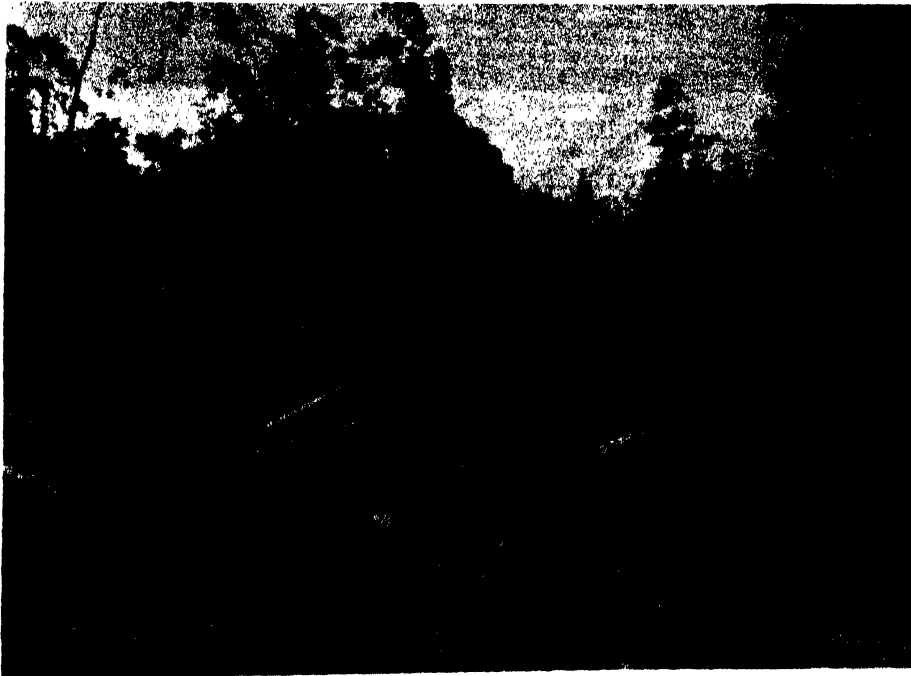
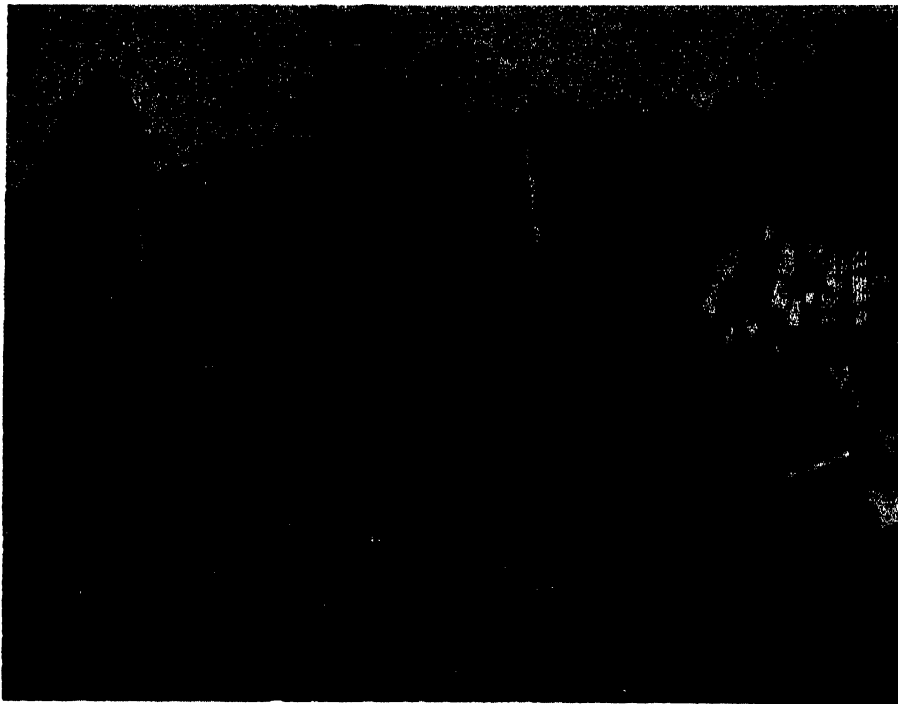


Fig. 4 NETWORK DIAGRAM FOR EQUIPMENT CHOICE



Manual loading of an agricultural tractor
with trailer by an eight-man crew.
Loading production was 6 m³/hour
(Troutbeck Sawmill Ltd.) (Photo H. Seppänen)

In cases where the machine and the elements of production are rented, a calculation of the owning and operating costs is necessary to derive the machine rate. The objective in developing a machine rate should be to arrive at a figure that as nearly as possible represents the cost of the work done under the operating conditions encountered and the accounting system in force. Most manufacturers of machinery supply data for the cost of owning and operating their equipment and they will serve as the basis of machine rates. Such data usually need modification to meet specific conditions of operation, however, and many owners of equipment prefer to prepare their own rates.



A unique trailer with rear-axle steering
designed by the Wattle Co. Ltd.
It was built to facilitate transport
of long poles around tight curves
on steep terrain (Photo: H. Seppänen)

3.2 Classification of costs .

The machine rate is usually, but not always, divided into fixed costs, operating costs and labour costs. For certain cash flow analyses, only items which represent a cash flow are included. Certain fixed costs, including depreciation and sometimes interest charges, are omitted if they do not represent a cash payment. In this paper, all fixed costs discussed below are included. For some analyses, labour costs are not included in the machine rate. Instead, fixed and variable costs are calculated. Labour costs are then added separately. This is sometimes done in situations where the labour associated with the equipment works a different number of hours from the equipment. In this paper, labour is included in the calculation of the machine rate.

3.2.1 Fixed costs

Fixed costs are those which can be predetermined as accumulating with the passage of time, rather than with the rate of work. They do not stop when the work stops and must be spread over the hours of work during the year. Commonly included in fixed costs are equipment depreciation, interest on investment, taxes, storage, and insurance.

3.2.2 Operating costs

Operating costs vary directly with the rate of work. They include the costs of fuel, lubricants, tyres, equipment maintenance and repairs.

3.2.3 Labour costs

Labour costs logically are those costs associated with employing labour and include direct wages, food contributions, transport, and social costs, including payments for health and retirement. The cost of supervision may also be spread over the labour costs.

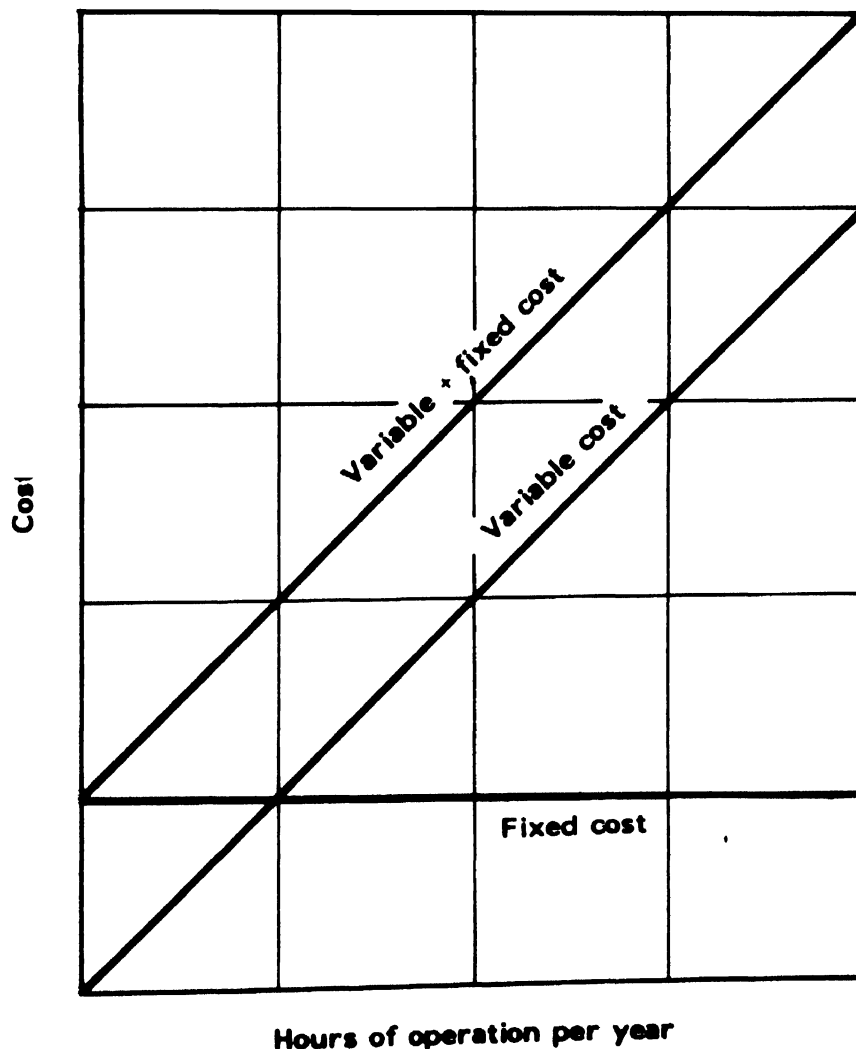


Fig. 5 EQUIPMENT COST MODEL

The machine rate is the sum of the fixed plus operating plus labour costs. The division of costs in these classifications is arbitrary, although accounting rules use a rigid classification. The key point is to separate the costs in a way that makes the most sense in explaining the cost of operating the men and equipment. For example, if a major determinant of equipment salvage value is the rate of obsolescence such as in the computer industry, the depreciation cost is largely dependent on the passage of time, not the hours worked. For a truck, tractor or power saw, a major determinant may be the actual hours of equipment use. The tractor's life could be viewed as the sand in an hour-glass which is permitted to drop only during the hours the equipment is working.

3.3 Definitions

3.3.1 Purchase price (P)

This is defined as the actual purchase cost of equipment including the standard attachments, optional attachments, sales taxes, and delivery costs. The most common pricing policies are the factory and delivered price. The factory price applies if the buyer takes title to the equipment at the factory and is responsible for shipment. The delivered price applies if the buyer takes title of the equipment at a specific delivery point. The delivered price usually includes freight, packing and insurance. Miscellaneous costs for installation or adaptation of the equipment to the logging system should be included in the initial investment cost. Special attachments may sometimes have a separate machine rate, if their lives differ from the main equipment and form an important part of the equipment cost.

3.3.2 Economic life (N)

This is the period over which equipment can operate at an acceptable operating cost and productivity. Economic life is generally measured in terms of years, hours, or in the case of trucks and trailers, kilometres. It depends upon a myriad factors, including physical deterioration, technological obsolescence and changing economic conditions. Physical deterioration can arise from such factors as corrosion, chemical decomposition, or wear and tear due to abrasion, shock and impact. These may result from normal and proper usage, abusive and improper usage, age, inadequate maintenance or lack of maintenance, or severe environmental conditions. Changing economic conditions such as fuel prices, tax investment incentives and the rate of interest can also affect the economic life of equipment.

Examples of ownership periods for some types of skidding and road construction equipment, based upon application and operating conditions, are shown in Table 6. Since the lives are given in terms of operating hours, the life in years is obtained by working backward, defining the number of working days per year and the estimated number of working hours per day. For equipment that works very few hours a day, the derived equipment lives may be very long and local conditions should be checked for the reasonableness of the estimate.

3.3.3 Salvage value (S)

This is defined as the price that equipment can be sold for at the time of its disposal. Used equipment rates vary widely throughout the world. In any given used-equipment market, however, factors which have the greatest effect on resale or trade-in value are the number of hours on the machine at the time of resale or trade-in, the type of jobs and operating conditions under which it worked, and the physical condition of the machine. Whatever the variables, the

Table 6

GUIDE FOR SELECTING OF OWNERSHIP PERIOD BASED ON APPLICATION AND OPERATING CONDITIONS

	ZONE A	ZONE B	ZONE C
WHEELED TRACTOR SCRAPERS	Level or favourable hauls on good haul roads. No impact. Easy-loading materials. Small 12 000 Hr Large 16 000 Hr	Varying loading and haul road conditions. Long and short hauls. Adverse and favourable grades. Some impact. Typical road-building use on a variety of jobs. 10 000 Hr 12 000 Hr	High impact condition, such as loading ripped rock. Overloading. Continuous high total resistance conditions. Rough haul roads. 8 000 Hr 8 000 Hr
OFF HIGHWAY TRUCKS AND TRACTORS	Mine and quarry use with properly matched loading equipment. Well maintained haul roads. Also construction use under above conditions. 25 000 Hr	Varying loading and haul road conditions. Typical road-building use on a variety of jobs. 20 000 Hr	Consistently poor haul road conditions. Extreme overloading. Oversized loading equipment. 15 000 Hr
WHEELED TRACTORS AND COMPACTORS	Light utility work. Stockpile work. Pulling compactors. Dozing loose fill. No impact. 15 000 Hr	Production dozing, pushloading in clays, sands, silts, loose gravels. Shovel clean-up. Compactor use. 12 000 Hr	Production dozing in rock. Push-loading in rocky, bouldering borrow pits. High impact conditions. 8 000 Hr
WHEELED LOADERS	Intermittent truck loading from stockpile, hopper charging on firm, smooth surfaces. Free flowing, low density materials. Utility work in governmental and industrial applications. Light snowplowing. Load and carry on good surface for short distances with no grades. 12 000 Hr 15 000 Hr	Continuous truck loading from stockpile. Low to medium density materials in properly sized bucket. Hopper charging in low to medium rolling resistance. Loading from bank in good digging. Load and carry on poor surfaces and slight adverse grades. 10 000 Hr 12 000 Hr	Loading shot rock (large loaders). Handling high density materials with counterweighted machine. Steady loading from very tight banks. Continuous work on rough or very soft surfaces. Load and carry in hard digging; travel longer distances on poor surfaces with adverse grades. 8 000 Hr 10 000 Hr
Small Large			

Table 6 (cont'd)

	ZONE A	ZONE B	ZONE C
TRACKED LOADERS	Intermittent truck loading from stockpile. Minimum travelling, turning. Free flowing, low density materials with standard bucket. No impact. 12 000 Hr	Bank excavation, intermittent ripping, basement digging of natural bed clays, sands, silts, gravels. Some travelling. Steady full throttle operation. 10 000 Hr	Loading shot rock, cobbles, glacial till, caliche. Steel mill work. High density materials in standard bucket. Continuous work on rock surfaces. Large amount of ripping of tight, rocky materials. High impact conditions. 8 000 Hr
TRACKED TRACTORS			
Small Large	Pulling scrapers, most agricultural drawbar, stockpile, coal-pile and landfill work. No impact. Intermittent full throttle operation. 12 000 Hr 22 000 Hr	Production dozing in clays, sands, gravels. Pushloading scrapers, borrow pit ripping, most land clearing and skidding applications. Medium impact conditions. 10 000 Hr 18 000 Hr	Heavy rock ripping. Tandem ripping. Pushloading and dozing in hard rock. Work on rock surfaces. Continuous high impact conditions. 8 000 Hr 15 000 Hr
MOTORGRADERS	Light road maintenance. Finishing. Plant and road mix work. Light snowplowing. Large amounts of travelling. 20 000 Hr	Haul road maintenance. Road construction, ditching. Loose fill spreading. Landforming, landlevelling. Summer road maintenance with medium to heavy winter snow removal. Elevating grader use. 15 000 Hr	Maintenance of hard pack roads with embedded rock. Heavy fill spreading. Ripping-scarifying of asphalt or concrete. Continuous high load factor. High impact. 12 000 Hr

Table 6 (cont'd)

EXCAVATORS	Shallow depth utility construction where excavator sets pipe and digs only 3 or 4 hours/shift. Free flowing, low density material and little or no impact. Most scrap handling arrangements. 12 000 Hr	Mass excavation or trenching where machine digs all the time in natural bed clay soils. Some travelling and steady, full throttle operation. Most log loading applications. 10 000 Hr	Continuous trenching or truck loading in rock or shot rock soils. Large amount of travel over rough ground. Machine continuously working on rock floor with constant high load factor and high impact. 8 000 Hr
WHEELED SKIDDERS	Intermittent skidding for short distances, no decking. Good underfoot conditions: level terrain, dry floor, few if any stumps. 12 000 Hr	Continuous turning, steady skidding for medium distances with moderate decking. Good underfooting: dry floor with few stumps and gradual rolling terrain. 10 000 Hr	Continuous turning, steady skidding for long distances with frequent decking. Poor underfloor conditions: wet floor, steep slopes and numerous stumps. 8 000 Hr

Adapted from Caterpillar Performance Handbook.

decline in value is greater in the first year than the second, greater the second year than the third, and so on. The shorter the work life of the machine, the higher the percentage of value lost in a year. In agricultural tractors, for example, as a general rule 40 to 50 percent of the value of the machine will be lost in the first quarter of the machine's life, and by the halfway point of lifetime 70 to 75 percent of the value will be lost. The salvage value is often estimated as 10 to 20 percent of the initial purchase price.

3.4 Fixed costs

3.4.1 Depreciation

The objective of the depreciation charge is to recognize the decline of value of the machine as it is working at a specific task. This may differ from the accountant's depreciation schedule which is chosen to maximize profit through the advantages of various types of tax laws and follows accounting convention. A common example of this difference is seen where equipment is still working many years after it was "written off" or arrived at zero "book value".

Depreciation schedules vary from the simplest approach, which is a straight-line decline in value in the absence of alternative information, to more sophisticated techniques which recognize the changing rate of value loss over time. The formula for the annual depreciation charge using the assumption of straight-line decline in value is

$$D = (P' - S)/N$$

where P' is the initial purchase price less the cost of tyres, wire rope, or other parts which are subjected to the greatest wear and can be easily replaced without effect upon the general mechanical condition of the machine.

3.4.2 Interest

Interest is the cost of using funds over a period of time. Investment funds may be borrowed or taken from savings or equity. If funds are borrowed, the interest rate is established by the lender and varies by locale and lending institution. If the money comes from savings, then opportunity cost or the rate this money would earn if invested elsewhere is used as the interest rate. The accounting practice of private firms may ignore interest on equipment on the ground that interest is a part of profits and therefore not a proper charge against operating equipment. Although this is sound from the point of view of the business as a whole, the exclusion of such charges may lead to the development of unrealistic comparative rates between machines of low and high initial cost. This may lead, in turn, to erroneous decisions in the selection of equipment.

Interest can be calculated by using one of two methods. The first method is to multiply the interest rate by the actual value of the remaining life of the equipment. The second, simpler, method is to multiply the interest rate by the average annual investment.

For straight-line depreciation, the average annual investment, AAI, is calculated as

$$AAI = (P-S)(N+1)/(2N) + S$$

Sometimes a factor of 0.6 times the delivered cost is used as an approximation of the average annual investment.

3.4.3 Taxes

Many equipment owners must pay property taxes or some type of usage tax on equipment. Taxes, like interest, can be calculated by either using the estimated tax rate multiplied by the actual value of the equipment or multiplying the tax rate by the average annual investment.

3.4.4 Insurance

Most private equipment owners will have one or more insurance policies against damage, fire, and other destructive events. Public owners and some large owners may be self-insured. It could be argued, however, that the cost of insurance is a real cost that reflects the risk to all owners and some allowance for destructive events should be allowed. Not anticipating the risk of destructive events is similar to not recognizing the risk of fire or insect damage in planning the returns from managing a forest. Insurance is handled in the same way as interest and taxes.

3.4.5 Storage and protection

Costs for equipment storage and off-duty protection are fixed costs, largely independent of the hours of use. Costs of storage and protection must be spread over the total hours of equipment use.

3.5 Operating costs

Operating costs, unlike fixed costs, change in proportion to hours of operation or use. They depend upon a variety of factors, many of which are to some extent under the control of the operator or equipment owner.

3.5.1 Maintenance and repair

These include everything from simple maintenance to the periodic overhaul of engine, transmission, clutch, brakes and other major equipment components, for which wear occurs primarily proportionally to use. Operator use or abuse of equipment, the severity of the working conditions, maintenance and repair policies, and the basic equipment design and quality all affect maintenance and repair costs.

The cost of periodically overhauling major components may be estimated from the owner's manual and the local cost of parts and labour, or by getting advice from the manufacturer. Another owner's experience with similar equipment and cost records under typical working conditions are valuable sources. If experienced owners or cost records are not available, the hourly maintenance and repair cost can be estimated as a percentage of hourly depreciation (Table 7).

Table 7

**MAINTENANCE AND REPAIR RATES AS A PERCENTAGE OF THE HOURLY
DEPRECIATION FOR SELECTED EQUIPMENT**

<u>Machine</u>	<u>Percentage rate</u>
Crawler tractor	100
Agricultural tractor	100
Rubber-tyred skidder with cable chokers	50
Rubber-tyred skidder with grapple	60
Loader with cable grapple	30
Loader with hydraulic grapple	50
Power saw	100
Feller-buncher	50

3.5.2 Fuel

The fuel consumption rate for a piece of equipment depends on the engine size, load factor, condition of the equipment, operator's habit, environmental conditions, and the basic design of equipment.

To determine the hourly fuel cost, the total fuel cost is divided by the productive time of the equipment. If fuel consumption records are not available, the following formula can be used to estimate litres of fuel used per machine hour:

$$\text{LMPH} = \frac{K \times \text{GHP} \times \text{LF}}{\text{KPL}}$$

where LMPH is the litres used per machine hour, K is the kg of fuel used per brake hp-hour, GHP is the gross engine horsepower at governed engine rpm, LF is the load factor in percent, and KPL is the weight of fuel in kg/litre. Typical values are given in Table 8. The load factor is the ratio of the average horsepower used to gross horsepower available at the flywheel.

Table 8

**WEIGHTS, FUEL CONSUMPTION RATES AND LOAD FACTORS
FOR DIESEL AND GASOLINE ENGINES**

Engine	Weight (KPL) kg/litre	Fuel consumption (K) kg/brake hp-hour	Load factor (LF)		
			Low	Medium	High
Gasoline	0.72	0.21	0.38	0.54	0.70
Diesel	0.84	0.17	0.38	0.54	0.70

3.5.3 Lubricants

These include engine oil, transmission oil, final drive oil, grease and filters. The consumption rate varies with the type of equipment, environmental working conditions (temperature), the design of the equipment and the level of maintenance. If actual data are lacking, the lubricant consumption in litres per hour for skidders, tractors and front-end loaders could be estimated as

$$\begin{aligned} Q &= .0006 \times \text{GHP} && (\text{crankcase oil}) \\ Q &= .0003 \times \text{GHP} && (\text{transmission oil}) \\ Q &= .0002 \times \text{GHP} && (\text{final drives}) \\ Q &= .0001 \times \text{GHP} && (\text{hydraulic controls}) \end{aligned}$$

These formulae include normal oil changes but no leaks. They should be increased 25 percent when machines are operating in heavy dust, deep mud, or water. In machines with complex and high-pressure hydraulic systems, such as forwarders, processors and harvesters, the consumption of hydraulic fluids can be much greater. Another rule of thumb is that the cost of lubricants and grease is 5 to 10 percent of the cost of fuel.

3.5.4 Tyres

Due to their shorter life, tyres are considered an operating cost. Tyre cost is greatly affected by the operator's habits, vehicle speed, surface conditions, wheel position, loadings, relative amount of time spent on curves, and grades. For off-highway equipment, if local experience is not available the following categories for tyre life based upon tyre failure mode could be used as guidelines with tyre life given in Table 9.

In zone A, almost all tyres wear through to tread from abrasion before failure. In zone B, most tyres wear out - but some fail prematurely from rock cuts, rips, and non-repairable punctures. In zone C, few if any tyres wear through the tread before failure due to cuts.

Table 9

GUIDELINES FOR TYRE LIFE OF OFF-HIGHWAY EQUIPMENT

Equipment	Tyre life in hours		
	Zone A	Zone B	Zone C
Motorgraders	8000	4500	2500
Wheeled scrapers	4000	2250	1000
Wheeled loaders	4500	2000	750
Skidders	5000	3000	1500
Trucks	5000	3000	1500

3.6 Labour costs

Labour costs include direct and indirect payments such as taxes, insurance payments, food and housing subsidies. Labour costs need to be carefully considered when machine rates are calculated, since the hours the labour works often differ from the hours the associated equipment works. What is important is that the user defines his convention and then uses it consistently. For example, in felling, the power saw rarely works more than four hours a day, even though the cutter may work six or more hours and may be paid for eight hours, including travel. If felling production rates are based upon a six-hour working day, with two hours of travel, the machine rate for an operator with power saw should consider four hours of actual power-saw use and eight hours of labour for six hours of production.

3.7 Variable effort cycles

The concept that men or equipment work at constant rates is an abstraction that facilitates measurements, record keeping, payment and analysis. There are some work cycles, however, which require such variable effort that it is more useful to construct machine rates for parts of the cycle. One important case is the calculation of the machine rate for a truck. When a log truck is waiting to be loaded, is being loaded, and is being unloaded, its fuel consumption, tyre wear and other running costs are not being incurred. For the standing truck, a different machine rate is often constructed using only the fixed cost and the labour cost for this part of the cycle. Part or all of the truck depreciation may be included.

If a single machine rate were used to estimate the unit cost for truck transport and this value were converted to a ton-km cost or $\$/m^3/km$ cost without removing the "fixed" cost of loading and unloading, then the "variable" cost of transport would be overestimated and could lead to erroneous results when a choice is being made between road standards or haul routes.

3.8 Animal rates

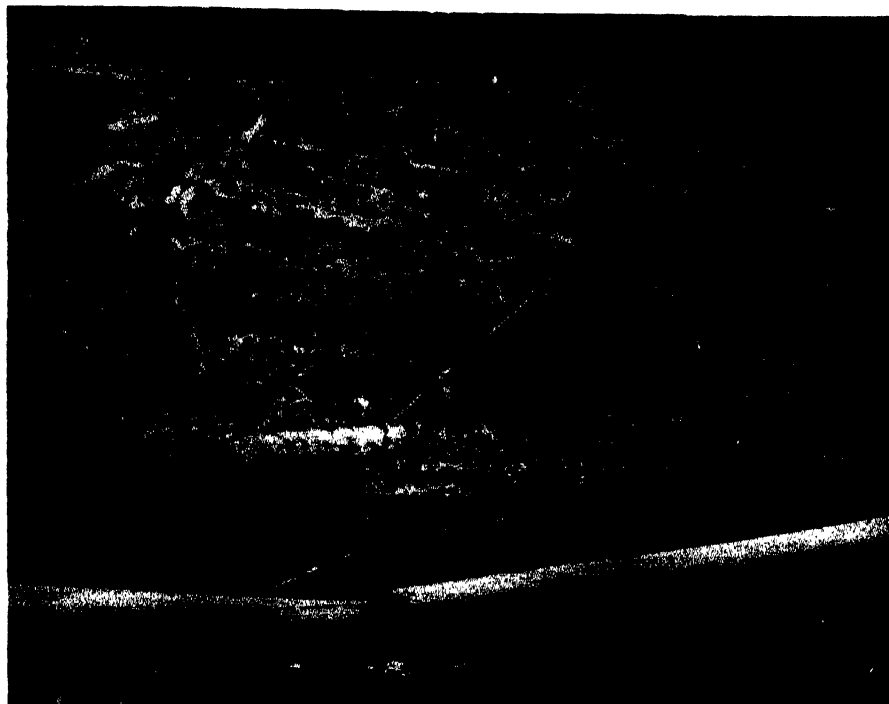
Calculation of the animal rate is similar to that for the machine rate, but the types of costs differ and merit additional discussion.

3.8.1 Ownership costs

Ownership costs include the investment cost of the animal or team, harness, yoke, cart, logging chains and any other investments with a life of more than one year. Other ownership costs include the upkeep of the animals.

The purchase price of the animal may include spare animals if the working conditions require that the animal receive rest more than overnight, such as every other day. To allow for the possibility of permanent injury, the animal purchase price may be increased to include extra animals, if the period for animal training is long. In other cases, accidents can be allowed for in the insurance premium.

The salvage cost for the animal has the same definition as for a machine, but in the case of the former, salvage value is often determined by its selling value for meat. Average annual investment, interest on investment, and any taxes or licences are treated in the same way as for machines.



A team of oxen being used to skid a log
in a clear-felling operation
(Photo: H. Seppänen)

To find the total ownership costs for animals, ownership costs for the animal, cart, harness and miscellaneous investments can be calculated separately and the hourly costs added together since they usually have lives of unequal length.

Animal support costs which do not vary directly with hours worked include pasture rental, food supplements, medicine, vaccinations, veterinary services, shoes, farrier services and any after-hours care such as feeding, washing or guarding. It could be argued that food and care requirements are related to hours worked and some part of these costs could be included in operating costs. Pasture area can be estimated by dividing the animal consumption rate by the forage production rate. Food supplements, medicine, vaccination, and veterinary schedules can be obtained from local sources such as agricultural extension agents.

3.8.2 Operating costs

Operating costs include repair and maintenance costs for harnesses, carts and miscellaneous equipment.

3.8.3 Labour costs

The labour cost in the animal rate is for the animal driver. For full-year operations it is calculated as the labour cost per year including social costs, divided by the average number of working days or hours for the driver.

Examples:

The appendix has examples of machine rates for a power saw, a tractor, a truck and a team of oxen. The examples show flexibility in format to meet alternative needs.

4. ESTIMATING ROAD CONSTRUCTION UNIT COSTS

4.1 Introduction

The unit cost of road construction in dollars per kilometre is the sum of the subunit costs of the road construction activities. Road construction unit costs are estimated by dividing the machine rates by the production rates for the various activities involved in the road construction activity. The various road construction activities considered here are surveying, clearing and grubbing, excavation, surfacing and drainage.

4.2 Surveying

Surveying and staking costs vary considerably, depending on type and size of the job, access, terrain and job location. One method of estimating production is to estimate the number of stakes which can be set per hour and the number of stakes which must be set per kilometre. For example, assume about 15 stakes can be set per hour with a two-man crew with the preliminary survey line already in place. A typical five-point section consists of two reference stakes, two slope stakes, and one final centreline stake.

The surveying production rate in km per hour is equal to the number of stakes the crew sets per hour, divided by the number of stakes required per km.

Example:

A survey crew is setting 300 stakes per km at a rate of 15 stakes per hour. The cost of a survey crew including transport is \$10 per hour.

$$\begin{aligned} P &= 15/300 = .05 \text{ km/hr} \\ UC &= 10/.05 = \$200/\text{km} \end{aligned}$$

4.3 Clearing and piling

The clearing and piling cost can be calculated by estimating the number of hectares of right-of-way to be cleared and piled per kilometre of road. The clearing and piling production rate in hours per km is the hectares per hour which can be cleared and piled per hour divided by the number of hectares per km to be cleared and piled. Clearing can be accomplished in a number of ways, including men with axes or power saw. Merchantable logs may be removed by skidder or tractor and the remainder piled by tractor for burning or decay. Felling rates and skidding rates for logging can be used to determine the cost of removing merchantable logs.

On gentle terrain, if a wide right-of-way is being cleared to permit sunlight to dry the road surface after frequent rains, the project might be estimated as a land clearing project. A method of estimating the total time per hectare required to clear, grub and pile with a tractor and shearing blade on gentle terrain is shown below.

4.3.1 Mechanized clearing

The clearing time will depend upon the size of the tractor and the number and size of the trees. The clearing time, T_c , in machine hours per hectare is

$$T_c = (X/60)(AB + M_1N_1 + M_2N_2 + M_3N_3 + M_4N_4 + DF/30)$$

where X is the hardwood density factor, A is the vine density factor, B is the base time per hectare, M is the minutes per tree in each diameter range, N is the number of trees per hectare in each diameter range, D is the sum of the diameters of all trees per hectare larger than 180 cm, and F is the minutes per 30 cm of diameter to cut trees with diameters greater than 180 cm.

Table 10

PRODUCTION FACTORS FOR FELLING WITH ROME KG BLADE

Tractor GHP	Factors B	Diameter range, cm				
		30-60 M_1	60-90 M_2	90-120 M_3	120-180 M_4	>180 F
140	100	0.8	4.0	9.0	-	-
200	62	0.5	1.8	3.6	11	3.6
335	45	0.2	1.3	2.2	6	1.8
460	39	0.1	0.4	1.3	3	1.0

$X = 1.3$ if the percentage of hardwood is >75 and $X = 0.7$ if percentage of hardwood is < 25 , $X = 1$ otherwise.

$A = 2.0$ if number of trees/ha is >1500 and $A = 0.7$ if number of trees/ha is < 1000 , $A = 1.0$ otherwise. Increase value of A by 1.0 if there are heavy vines.

For hectares which must be cleared and where stumps must be removed (grubbed), multiply the total time for clearing by a factor of 1.25.

4.3.2 Mechanized piling

An equation to calculate the piling time per hectare, T_p , when a rake or an angled shearing blade is used is

$$T_p = (1/60)(B + M_1N_1 + M_2N_2 + M_3N_3 + M_4N_4 + DF/30)$$

where the variables are defined as above. Table 11 shows the coefficients for piling when stumps have not been removed.

When piling includes piling of stumps, the total piling time should be increased by 25 percent.

Table 11

PRODUCTION FACTORS FOR PILING IN WINDROWS

Tractor GHP	Factors B	Diameter range, cm				
		30-60 M_1	60-90 M_2	90-120 M_3	120-180 M_4	>180 F
140	185	0.6	1.2	5.0	-	-
200	135	0.4	0.7	2.7	5.4	-
335	111	0.1	0.5	1.8	3.6	0.9
460	97	0.08	0.1	1.2	2.1	0.3

Example:

Five hectares per km of right-of-way are being cleared for a road (extra width is being used to help the road dry after rains). Of the 5 hectares, 1.2 hectares per km will need to have the stumps removed. Tractor machine rate is \$80 per hour. All material will be piled for burning. Work is being done by a 335-hp bulldozer. The average number of trees per hectare is in the following table.

Table 12

DATA FOR CLEARING, GRUBBING AND PILING EXAMPLE

Number of trees < 30 cm	Diameter range, cm				
	30-60 N_1	60-90 N_2	90-120 N_3	120-180 N_4	>180 D
1100	35	6	6	4	60

Note: Less than 1 tree > 180 cm per hectare.

$$T_c = (X/60)(AB + M_1N_1 + M_2N_2 + M_3N_3 + M_4N_4 + DF/30)$$

$$T_c = (1/60)[(1)(45) + (.2)(35) + (1.3)(6) + (2.2)(6) + (6)(4) + (60)(1.8)/30] = 1.68 \text{ hr/ha}$$

$$T_p = (1/60)(B + M_1N_1 + M_2N_2 + M_3N_3 + M_4N_4 + DF)$$

$$T_p = (1/60)[111 + (.1)(35) + (.5)(6) + (1.8)(6) + (3.6)(4) + (.9)(60)/30] = 2.41 \text{ hr/ha}$$

$$\text{Total tractor time/km} = 5(1.68 + 2.41) + 1.2(.25)(1.68 + 2.41)$$

$$= 21.7 \text{ hr/km}$$

$$P = 1/21.7 = .046 \text{ km/hr}$$

$$UC = 80 \times 21.7 = \$ 1736/\text{km}.$$

4.4 Earthwork

Earthwork cost is calculated by estimating the number of cubic metres of common material and rock which must be moved to construct the road. The earthwork production rate is calculated as the cubic metres per hour which can be excavated and placed, divided by the number of cubic metres per km to be excavated.

Local road construction superintendents can often directly estimate the number of metres per hour that their equipment can build road just by looking at the topography. The engineer's method is to estimate the number of cubic metres to be excavated. Formulae and tables for calculating earthwork quantities as a function of sideslope, road width, cut and fill slope ratios are available, as are production rates for common bulldozers and hydraulic excavators.

For example, a 6-m subgrade on a 30 percent slope with a 1.5:1 fill slope and 0.5:1 cut slope with a 30-cm ditch and a 20-percent shrinkage factor would be approximately 2100 bank cubic metres per km for a balanced section.

An average production rate in common material from an equipment performance handbook might be 150 bank cubic metres per hour for a 300-hp power shift tractor with ripper. The tractor cost is \$80/hr. The rate of excavation would be

$$P = (150 \text{ m}^3/\text{hr})/(2100 \text{ m}^3/\text{km}) = .07 \text{ km/hr}$$

$$UC = 80/.07 = \$1143/\text{km}$$

If the earthwork is not being placed or sidecast within 50 m of the cut, the production rate for pushing the material to the placement location must be made. Scrapers or excavators and dump trucks may be used.

Excavation rates in rock vary with the size of job, hardness of rock and other local conditions. Often there is a local market price for blasting. Estimates of blasting production can be made by knowing the size of equipment and the type of job. For example, a 10-cm track-mounted drill and 25 m³-per-minute air-compressor may prepare 40 m³ per hour for small, shallow blasts and 140 m³ per hour for larger, deeper blasts including quarry development to produce rock surfacing. A major cost will be explosives. For example, 0.8 kg of explosive such as Tovex may be used per cubic metre of rock at a cost of approximately \$2 per kg.

4.5 Finish grading

Finish grading of the subgrade can be estimated by determining the number of passes a grader must make for a certain width of subgrade and the speed of the grader. This number can be converted to the number of hours per hectare of

subgrade. For example, a 120-hp grader may require about 10 hours of productive machine time without delays per hectare of subgrade or 0.1 hectares per hour. Similarly, the rate of pulling ditches per kilometre can be estimated. The production rate for final grading of a 6-m subgrade would then be

$$P = (0.1 \text{ ha/hr}) / (0.6 \text{ ha/km}) = .17 \text{ km/hr.}$$

If the grader cost is \$20/hr, the unit cost of grading is

$$UC = 20 / .17 = \$118/\text{km.}$$

4.6 Surfacing

Surfacing costs are a function of the type of surfacing material, the quantity of surfacing material per square metre, and the length of haul. Local information is the best guide in constructing surfacing costs, due to the wide range of conditions that can be encountered.

Natural gravel from streams may require only loading with front-end loaders directly to dump trucks, transporting and spreading; it may or may not be compacted.

Laterite may be ripped by crawler tractor, loaded by front-end loader, transported, spread and grid-rolled with a sheeps-foot roller to produce a sealed running surface.

Rock may have to be blasted, loaded into crusher, stockpiled, reloaded, transported, spread and compacted.

The costs for each of these operations can be developed by estimating the equipment production rates and machine rates. For example, a relatively complex surfacing operation requires the developing of a 20 000-m³ solid rock source (26 400 m³ in the road prism) to surface 26.4 km of road. The operation will include shooting and crushing, loading, transporting and spreading rock as follows:

To open up rock source use data from clearing and common excavation:

(a) To clear and excavate rock:

<u>Equipment</u>	<u>Machine hours</u>	<u>Machine rate</u>	<u>Cost</u>
Tractor	27	72.00	1944.00

Cost per cubic metre of solid rock = \$0.10

(b) To drill and blast at a production rate of 140 m³ per hour:

<u>Equipment</u>	<u>Machine hours</u>	<u>Machine rate</u>	<u>Cost</u>
Drills	1.0	60.00	60.00
Compressor	1.0	55.00	55.00
Explosives	0.8 kg x \$2.0/kg x 140 m ³		224.00
			339.00

Cost per cubic metre of solid rock = \$2.42

(c) To crush 225 tons per hour (2.6 tons/solid m³)

<u>Equipment</u>	<u>Machine hours</u>	<u>Machine rate</u>	<u>Cost</u>
Tractor	0.5	72.00	36.00
Loader	1.0	90.00	90.00
Crusher	1.0	90.00	90.00
Stacker	1.0	15.00	15.00
Generator	1.0	20.00	20.00
			<u>251.00</u>

Cost per cubic metre of solid rock = \$2.90

(d) To load, transport and spread 20,000 m³ of rock:

1 truck x 3 loads/hr x 20 tons/load x m³/2.6 ton = 23 m³/hr

If 4 trucks are used:

<u>Equipment</u>	<u>Machine hours</u>	<u>Machine rate</u>	<u>Cost</u>
Four trucks	872	50.00	43 600
Loader	218	90.00	19 600
Tractor	218	72.00	15 700
Grader	20	60.00	1 200
			<u>80 100</u>

Cost per cubic metre of solid rock = \$4.01.

The total unit cost per cubic metre of rock spread on the road is as follows:

<u>Activity</u>	<u>\$/m³ solid</u>	<u>\$/m³ prism</u>	<u>\$/km</u>
Develop pit	0.10	0.08	80
Drill and blast	2.42	1.83	1830
Crush	2.90	2.20	2200
Load, transport and spread	<u>4.01</u>	<u>3.03</u>	<u>3030</u>
	9.43	7.14	7140

Equipment balancing plays an important role in obtaining the minimum cost per cubic metre for surfacing. In some areas, market prices for various types of surfacing may be standard and tradeoffs between aggregate cost, aggregate quality and hauling distance will have to be evaluated. Since surfacing is often expensive, a surveying crew is sometimes added to stake and monitor the surfacing operation.

4.7 Drainage

Drainage costs vary widely with the type of drainage being installed. The costs of drainage dips (water bars), culverts and bridges are often expressed as a cost per lineal foot, which can then be easily applied in road estimating.

Local values for cost per lineal foot for culverts and different types of bridges are generally available. If not, constructed costs can be found by using time study data. An example is given below:

A 45-cm culvert, 10 m long, is being installed. Experience indicates that a small backhoe and operator and two labourers can install three culverts a day. The culvert crew uses a flat-bed truck to transport themselves and the pipe each day.

To install three culverts:

<u>Equipment</u>	<u>Machine hours</u>	<u>Machine rate</u>	<u>Cost</u>
Backhoe	6	50.00	360.00
Truck	9	12.00	108.00
Pipe costs	30 x \$15/metre		<u>450.00</u>
			918.00

Cost per lineal metre of culvert = \$30.60 per metre.

Alternatively, the cost could be stated as \$306 per culvert or if there were an average of four culverts per km then \$1224 per km.

5. ESTIMATING LOGGING UNIT COSTS

5.1 Introduction

Logging unit costs are estimated by dividing machine rates by the production rates for the various logging activities. Logging components considered here are felling, bucking, skidding, loading and transport.

5.2 Felling and bucking

The major variables in felling and bucking are the tree diameter and the number of bucking cuts after felling. An example of the time to fell and buck a tree is

$$T = a + b D^2 + c B$$

where T is the time per tree in minutes, b is the minutes per unit diameter, D is the diameter, c is the time per bucking cut and B is the number of bucking cuts. The coefficient a is the time per tree that is not related to diameter, such as walking between trees or preparing to cut. Sometimes terrain and brush are taken into account by using equations of the form

$$T' = (1+f) T$$

where f is an adjustment for terrain or brush. The production rate, P, is in cubic metres per hour and can be expressed as

$$P = V/T$$

where V is the volume per tree and T is the time per tree. The unit cost of felling is

$$UC = C/P$$

where C is the machine rate for felling and bucking and P is the production rate.

Example:

A power saw and operator cost \$5.00 per hour and the time to fell and buck a tree is

$$T = 4.0 + .005 D^2 + 2.0 B.$$

For a tree with a volume of 6 m³, dbh of 80 cm and 1 bucking cut:

$$T = 4.0 + .005 (80)(80) + 2.0 (1) = 38.0 \text{ min} = 0.63 \text{ hr}$$

$$P = V/T = 6/0.63 = 9.5 \text{ m}^3 \text{ per hr}$$

$$UC = 5/9.5 = \$0.52 \text{ per m}^3$$

For a tree with a volume of 1.25 m³, dbh of 40 cm and 1 bucking cut:

$$T = 4.0 + .005 (40)(40) + 2.0 (1) = 14.0 \text{ min} = 0.23 \text{ hr}$$

$$P = V/T = 1.25/.23 = 5.4 \text{ m}^3 \text{ per hr}$$

$$UC = 5/5.4 = \$0.93 \text{ per m}^3$$

5.3 Skidding

Skidding production is estimated by dividing the volume per load by the minutes per round trip. The round-trip time, T, is composed of travel unloaded, hooking, travel loaded and unhooking.

$$T = a N + b_1 x_1 + b_2 x_2$$

where a is the combined time for hooking and unhooking per log, b₁ is the minutes per metre for unloaded travel, b₂ is the minutes per metre for loaded travel, x₁ is the distance from the landing to load pickup point and x₂ is the distance from the load pickup point to the landing. If the outhaul distance and inhaul distance are the same, the round-trip time can be expressed as

$$T = a N + b x$$

where b is the minutes per round-trip distance and x is the one-way distance. The coefficient b is calculated as

$$b = \frac{v_1 + v_2}{v_1 v_2}$$

where v₁ is the travel speed unloaded and v₂ is the travel speed loaded.

Example:

A skidder is bringing in 3 logs with a volume of 4 m³. The unloaded velocity is 200 m per minute, the loaded velocity 100 m per minute. The hooking

time is 1.5 minutes per log and the unhooking and decking time is 1.1 minutes per log. The skidding distance is 300 m. The machine rate for the skidder and crew is \$40 per hour.

$$T = (2.6)(3) + 300/200 + 300/100 = 12.3 \text{ min} = .21 \text{ hr}$$

$$P = 4/.21 = 19.5 \text{ m}^3 \text{ per hour}$$

$$UC = 40/19.5 = \$2.05 \text{ per m}^3$$

alternatively,

$$b = (200 + 100)/[(200)(100)] = .015 \text{ min/m}$$

$$T = (2.6)(3) + .015 (300) = 12.3 \text{ min.}$$

The cost of hooking, unhooking and decking is

$$UCF = (C/60)(aN)/V$$

$$UCF = (40/60)(3)(2.6)/4 = \$1.30 \text{ per m}^3$$

The cost per cubic metre of wood per unit distance (measured one-way), UCV, is

$$UCV = (C/60) (b)/V$$
$$UCV = (40/60)(.015)/4 = \$0.0025/\text{m}^3/\text{m.}$$

At a skidding distance of 300 m

$$UC = UCF + UCV = 1.3 + (.0025)(300) = \$2.05 \text{ per m}^3$$

The same method can be used to estimate the skidding costs with agricultural tractors and trailers, or animals, or with cable systems.

Another example, this time with oxen:

A team of oxen brings in one log with a volume of 0.8 m³. The unloaded velocity is 30 m per minute, and the loaded velocity is 30 m per minute. The hooking time is 2.0 minutes and the unhooking and watering time is 5 minutes. The skidding distance is 100 m. The rate for the oxen and driver is \$3.0 per hour.

$$T = (7) + 100/30 + 100/30 = 13.7 \text{ min} = .23 \text{ hr}$$

$$P = .8/.23 = 3.48 \text{ m}^3 \text{ per hour}$$

$$UC = 3/3.48 = \$0.86 \text{ per m}^3$$

5.4 Loading

Loading production is estimated by dividing the volume per cycle by the minutes per cycle.

The time per log for loading single logs is often as simple as

$$T = a$$

where a is the time per cycle.

Example:

A truck is being loaded by hydraulic knuckleboom loader, which is loading 1-m³ logs individually at an average rate of 2 logs a minute. To prepare for loading the trucks, however, the loader spends 30 minutes an hour in sorting logs. The cost of the loader is \$40/hr. What is the loading production rate and cost?

When the loader is actually loading logs, the production rate is

$$P = (1.0)/.5 = 2.0 \text{ m}^3/\text{min} = 120 \text{ m}^3/\text{hr}$$

but the loading production per machine hour is 60 m³.

The cost of log sorting can be shown either as a reduced effective rate of log loading or as a separate unit cost of the total logging unit cost. Of course, if the loader operator were just trying to keep busy, a superior alternative might be to shut down the loader between trucks. If the sorting cost is included in the loading cost the unit cost of loading is then

$$UC = 40/60 = \$0.67 \text{ per m}^3$$

5.5 Truck transport

The method of estimating truck production depends upon the purpose of the analysis. If truck production is being calculated for the purpose of determining the number of trucks needed for truck haul, then the average truck load is divided by the total round-trip time, including unloaded travel time, loading time, loaded travel time, and unloading time. The calculation is similar to that for skidding with the round-trip travel time, T, expressed as

$$T = a + b_1 x_1 + b_2 x_2$$

where a is the combined time in hours for loading and unloading, b₁ is the hours per km for unloaded travel, b₂ is the hours per km for loaded travel, x₁ is the distance from the landing to load pickup point and x₂ is the distance from the load pickup point to the landing. If the outhaul distance and inhaul distance are the same, the round-trip time can be expressed as

$$T = a + b x$$

where b is the hours per round-trip km and x is the one-way distance. The coefficient b is calculated as

$$b = \frac{v_1 + v_2}{v_1 v_2}$$

where v₁ is the travel speed unloaded and v₂ is the travel speed loaded.

Example:

A 22-ton truck carries an average of 30 m³ per trip. The haul route is 35 km. The unloaded truck travels 40 km per hour: loaded, it travels 25 km per hour. The combined waiting and loading time is 30 minutes per load and the

combined waiting and unloading time is 20 minutes per load. What is the production per hour? The cost per truck standing hour is \$20 and the cost per truck running hour is \$30.

$$T = (30+20)/60 + 35/40 + 35/25 = 3.11 \text{ hrs}$$

$$P = 30/3.11 = 9.65 \text{ m}^3/\text{hr}.$$

The "fixed" unit cost of truck standby for loading and unloading is:

$$\text{UFC} = (\$20/\text{hr})(30+20 \text{ min})/60 \text{ min/hr}/30 \text{ m}^3 = \$0.56 \text{ per m}^3.$$

The "variable" unit cost of truck travel is:

$$\text{UVC} = (\$30/\text{hr})(35/40 \text{ hr} + 35/25 \text{ hr})/30 \text{ m}^3 = \$2.28 \text{ per m}^3$$

or expressed on a ton-km basis:

$$\text{UVC} = (\$30/\text{hr})(35/40 \text{ hr} + 35/25 \text{ hr})/22 \text{ t}/35 \text{ km} = \$0.089 \text{ t-km}.$$

The total unit cost of truck haul is:

$$\text{UC} = \text{UFC} + \text{UVC} = 0.56 + 2.28 = \$2.84 \text{ per m}^3.$$

Appendix

MACHINE OPERATING COST ESTIMATES

Note: All costs in the following estimates are in US\$.

1. McCulloch Pro Mac 650 power saw

	Motor cc	60	Delivered cost	400
	Life in hours	1 000	Hours per year	1 000
Fuel:	Type	Gas	Price per litre	0.56
Oper.:	Rate per day	5.50	Social costs	43.2%

<u>Cost component</u>		<u>Cost per hour</u>
(a) Depreciation	= $\frac{\text{delivered cost} \times .9}{\text{life in hours}}$	0.36
(b) Interest at 10%	= $\frac{\text{delivered costs} \times .6 \times \text{rate}}{\text{average hours per year}}$	0.03
(c) Insurance	= $\frac{\text{delivered costs} \times .6 \times .03}{\text{average hours per year}}$	0.01
(d) Taxes	= $\frac{\text{annual tax amount}}{\text{average hours per year}}$	--
(e) Labour	= $\frac{\text{labour cost per year} \times (1+f)}{\text{average hours per year}}$	1.89 <u>1/</u>
	where f = social costs of labour as decimal	
	<u>Sub-total</u>	2.29
(f) Fuel	= $0.86 \text{ l/hr} \times .95 \times \text{CL}$ + $0.86 \text{ l/hr} \times .05 \times \text{CO}$	0.70
	where CL = cost of gas, CO = cost of oil	
(g) Lub. oil for bar and chain	= fuel cons. $2.5 \times \text{CO}$	0.45
(h) Servicing and repairs	= $1.0 \times \text{depreciation}$	0.36
(i) Chain, bar and sprocket		0.67
(j) Other		0.22
	<u>Total</u>	4.69 <u>2/</u>

1/ Labour based on 240 days per year.

2/ Add 0.04 if standby saw is purchased.

2. CAT D-6D PS tractor

	Gross hp	140	Delivered cost	142 000 <u>1/</u>
	Life in hours	10 000	Hours per year	1 000
Fuel:	Type	Diesel	Price per litre	0.44
Oper.:	Rate per day	12.00	Social costs	43.2 %
Help:	Rate per day	5.00	Social costs	43.2 %

<u>Cost component</u>			<u>Cost per hour</u>
(a)	Depreciation	= $\frac{\text{delivered cost} \times .9}{\text{life in hours}}$	12.78
(b)	Interest at 10 %	= $\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	8.52
(c)	Insurance at 3%	= $\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	2.56
(d)	Taxes at 2%	= $\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	1.70
(e)	Labour	= $\frac{\text{labour cost per year}^{2/}}{\text{average hours per year}} \times (1+f)$	5.84
where f = social costs of labour as decimal			
			<u>Sub-total</u> 31.40
(f)	Fuel	= .20 x GHP x LF x CL	6.65
where GHP = gross engine horsepower CL = fuel cost per litre LF = load factor (.54)			
(g)	Oil and grease	= 0.10 x fuel cost	0.67
(h)	Servicing and repairs	= 1.0 x depreciation	12.78
(i)	Other (cable, misc.)		5.00
			<u>Total</u> 56.00

With blade, ROPS, winch, integral arch.
Labour based upon 240 days per year.

3. Pair of oxen for skidding

	Gross hp	--	Delivered costs	2 000
	Life in years	5	Days per year	125
Labour	Rate per day	7.00	Social costs	43.2 %

<u>Cost component</u>			<u>Cost per day</u>
(a)	Depreciation	= $\frac{\text{delivered cost} \times .65}{\text{life in days}}$	2.08 ^{1/}
(b)	Interest at 10%	= $\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average days per year}}$	0.96
(c)	Taxes	= $\frac{\text{annual tax amount}}{\text{average days per year}}$	--
(d)	Pasture	= $\frac{\text{pasture rental for year}}{\text{average days per year}}$	1.10
(e)	Food supplements		1.36
(f)	Medicine and veterinary services		0.27
(g)	Driver	= $\frac{\text{labour cost per year} \times (1+f)}{\text{average days per year}}$	9.62 ^{2/}
where f = social costs of labour as decimal			
(h)	After-hours feeding and care		2.62
(i)	Other (harness and chain)		1.00
<u>Total</u>			19.01

1/ Oxen sold for meat after 5 years.

2/ Driver works with two pairs of oxen, 250 days a year.

4. Ford 8000 LTN truck

	Gross hp	200	Delivered costs	55 000
	Life in hours	15 000	Hours per year	1 500
Fuel:	Type	Diesel	Price per litre	.26
Tyres:	Size 10 x 22	Type Radial	Number	10
Labour:	Rate per day	12.00	Social costs	43.2%

<u>Cost component</u>			<u>Cost per hour</u>
(a) Depreciation	=	$\frac{\text{delivered cost} \times .9 - \text{tyres}}{\text{life in hours}}$	3.07
(b) Interest at 10%	=	$\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	2.20
(c) Insurance at 3%	=	$\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	0.66
(d) Taxes at 2%	=	$\frac{\text{delivered cost} \times .6 \times \text{rate}}{\text{average hours per year}}$	0.44
(e) Labour	=	$\frac{\text{labour cost per year} \times (1+f)}{\text{average hours per year}}$	3.30 ^{1/}
where f = social costs of labour as decimal			
	Standing cost	<u>Sub-total</u>	9.67
(f) Fuel	=	.12 x GHP x CL	6.24
where CL = cost per litre for fuel			
(g) Oil and grease	=	0.10 x fuel cost	0.62
(h) Servicing and repairs	=	1.5 x depreciation	4.61
(i) Tyres	=	$1.2 \times \frac{\text{replacement cost}}{1500 \text{ hours}}$	2.40
(j) Other (chains, tighteners)			0.20
	Travelling cost	<u>Total</u>	23.74

1/ Labour is for 240 days plus 20 % overtime.

SOME THOUGHTS ON COST AND PRODUCTION CONTROL IN HARVESTING IN ZIMBABWE

by

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1. INTRODUCTION

The Wattle Company in Zimbabwe is actively involved in wattle bark production and this process will be used in this paper to illustrate some of the basic principles of cost and production control systems.

As a background: the Wattle Company was established in Zimbabwe some 40 years ago with the purpose of producing wattle extract to supply to local and export markets. The company bought land in the eastern districts of Zimbabwe and the development of wattle plantations proceeded until a peak in hectareage of 25,000 hectares was reached in the early nineteen sixties. But with the world demand for wattle tanning extract shrinking steadily as a result of the introduction of other tanning materials and to some extent a move away from leather products, the area of wattle plantations was reduced over the years and now stands at 14,000 hectares. During this period the company diversified into other plantation crops and now has extensive areas of pine, eucalyptus and coffee plantations. It does, however, continue to produce wattle extract of which 90 percent is exported from Zimbabwe.

The Wattle Company is the only producer of wattle extract in Zimbabwe and owns approximately 95 percent of the wattle plantations in this country. The type of wattle grown is the black wattle (*Acacia mearnsii*). It is a relatively fast-growing hardwood tree and is usually felled at about ten years of age, by which time the bark has matured in terms of tannin content. At felling, the bark is stripped manually and bundled for transport to the factory. The exploitation process is a relatively simple one with very little mechanization involved.

The factory process is basically a diffusion process with the tannin present in the bark being washed out under pressure in boiling water. This extract from the bark is then evaporated until the moisture content reaches about 18 percent and then it is packed and ready for sale.

2. THE IMPORTANCE OF CONTROL

The price of a product is certainly one of the most critical aspects in any production process, and this is particularly true in the timber industry where we compete with a number of other materials for a consumer's choice; for example: steel being used for telephone and fencing poles and for roof trusses; plastics in furniture and flooring; brick in housing, and so on.

It should be a company's aim to sell as much as it can of the product it produces, at a reasonable margin. In a broad sense the volume of a product that is bought by consumers is inversely proportional to its price. Price in an economically viable entity has in turn a direct relation to the cost of production and this obviously in turn to the productivity of the resources employed in producing the product.

A factor common to the timber industry is that it is a capital-intensive industry usually carrying a large element of fixed overhead costs. High volume production is therefore often a prerequisite for low unit costs and presumably low, or at least competitive, prices and a higher volume of sales. This assertion is naturally a simplification and there are many other factors that influence the consumption of timber products; however, the principle, when related to the subject of cost and production control, is a sound and valid one. Therefore the aim must be to control costs, keep them low, and keep prices competitive to entice consumers faced with a choice of materials to choose timber products.

With the increasing cost of labour, machinery, land and management, a high level of productivity must be sustained in these four elements so that forest products remain competitive in both internal and export markets. This is briefly some of the theory behind the endeavour to control costs and production and strive for efficiency in these aspects.

3. PRACTICAL ASPECTS OF COST AND PRODUCTION CONTROL

In order to achieve the goal of optimally productive resources, an effective system of cost and production control is essential. There are four requirements for the implementation of such a system:

1. Accurate and efficient recording of cost and production data;
2. A quick and relevant analysis of these data and the derivation of relevant and useful information;
3. Effective and speedy communication of this information to the decision-makers (forest managers);
4. Action based on this information.

An example based on wattle-bark production will be used to illustrate such a system. This particular system and the principles behind it could, however, apply to the production of other forest products.

3.1 Recording

3.1.1 Production data

The basic document of production recording is the bark stripping production sheet. The daily production (in kg) of each worker is weighed manually and recorded on this sheet. The total daily production and number of stripping workers is then totalled and transferred to a stripping production control sheet. The purpose of this sheet is to monitor individual and total production levels. For instance, if production drops below a certain level it usually indicates that the work is getting more difficult and the wage schedule and task levels can be adjusted accordingly. Wattle stripping is, incidentally, paid for on an incentive wage scale.

At the same time, bark is being delivered to the factory and vehicle tonnages are recorded across the weighbridge. The forest managers receive these weights and record them on a factory deliveries schedule. Its purpose is to provide comparison of field (manual scale weighing) and factory (weighbridge) weights. Significant differences will highlight inaccuracies in field weighing; for instance, an inaccurate scale or fraudulent over-payment; and corrective action is taken.

From these production sheets, information such as yield per hectare, productivity of workers, relevant ease/difficulty of work, can be obtained.

This information can then be used in future planning (optimum age to fell in terms of bark production, etc.), derivation of new wage scales, task levels, areas requiring training or improvement in methods, and so on. So much then for the recording of production data from which a physical measure of productivity is derived.

3.1.2 Cost data

From the stripping production sheet, a cash figure is attached to the bark production. These figures are transferred to a time book and this document shows the basic allocation of a worker's activity and is used for allocating costs of production for particular jobs. (Again, cost "productivity" is derived.)

The information in the time book is transferred to a wages book, an administrative document used to calculate and record the payment of wages.

3.2 Analysis

Jobs are allocated on a monthly basis to split labour activity into the various jobs. These costs are then totalled and the total cost of production is obtained.

The monthly production figures (tonnes) are then brought in and a unit cost of production obtained.

At the same time tractor and vehicle usage is recorded in log books (hours or kilometres) and their costs recorded in individual vehicle accounts. The same process as for labour recording is followed and a cost per unit (per km or per hour) arrived at.

These allocations and their derivations (\$/tonne; tonnes/labour unit, etc.) all form part of the analysis stage of cost and production control.

3.3 Communication and action

Results of these analyses are then communicated to the decision-makers who are able to act with a sound knowledge of the situation.

4. REMARKS

4.1 The importance of a system

Although the foregoing is simple and really common sense, it is surprising how many enterprises have good systems but one or two of the links in the process are broken and the system becomes ineffective. For instance, information is sometimes tirelessly recorded but then no analysis is done and the managers continue on blindly; or analysis is done long after the information loses its relevance or after corrective action is still possible.

It is essential that the four elements are kept linked, as a system of control is essentially a process; if there are any breaks in the process, the system collapses.

The principle of the system is possibly the most important aspect of cost and production control. The system should be kept simple and efficient in the information recorded. A response to the information must be made by deriving a relevant analysis, and then response to the analysis must be made by taking action (in other words, managing) when required.

4.2 The timber industry in Zimbabwe

Private enterprise in Zimbabwe is represented by the Timber Council, with the parastatal Forestry Commission having observer status on this body.

Three years ago, the Timber Council formed a sub-committee to monitor log production costs. On this sub-committee all major producers are represented. Once a year, it produces an updated cost of the production of roundwood at roadside. This figure serves as a monitor of inflation in timber production and assists producers to gauge their performance against the industry average.

The results produced in the period of the sub-committee's functioning have shown that in the two years 1983-85, the cost of production of a cubic metre of roundwood at roadside went up by some 39 percent.

We live in a time of high inflation and cost increases of this magnitude again highlight the importance of having an effective system of cost control.



Debarking a black wattle (Acacia mearnsii)
stem with a hatchet. The stems were used as
transmission and telephone poles as well
as fencing poles
(The Wattle Co. Ltd.) (Photo: H. Seppänen)

INTRODUCTION TO LOG MEASURING, BUCKING AND GRADING RULES

by

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1. GENERAL

When the main functions of a forest stand are not only to keep the ground covered with vegetation but to use its end product, the harvested timber, economically, the owner of the raw material - usually the owner of the forest - should remember that his investment is unrealized until he makes a decision on the harvesting. The end product will have value if it can be used for something, but that value can be increased by many times if proper care is taken to ensure that the material is efficiently used.

The basic rules of demand and supply apply in the timber trade as elsewhere. When the possible ways of using a forest stand are being considered, there are the two approaches: (a) a certain type or types of material may be obtained from that stand, and (b) a buyer needs a certain type or types of material, usually for some specific purpose. There are cases where these two aspects are not compatible; for example, when the buyer needs the raw material for solid mahogany furniture and all the seller has to offer is small-dimension pine, then obviously the seller is not and cannot become the solution to that particular buyer's problem.

Usually, however, he will not need to look far to find what he wants. As man is mostly a rational being it is seldom that demand and supply within a larger area do not find some meeting point. A wood-manufacturing industry is expensive to establish and is not usually started without some investigation and calculation of the availability of the necessary raw material - although it is quite common for demand and supply not to be always in balance. Normally it is a question of making the supply meet the particular requirements of the demand; the wanted material needs to be handled so that the prospective buyer will accept the result as suitable for his specific purpose.

It is self-evident that the owner of a forest stand tries to juggle the situation to his own advantage, by estimating the possibilities of his raw material and handling it in such a way to obtain the highest profit. To achieve this he must know, firstly, the demand in the area, and secondly, what his forest contains and what he can reasonably expect to make from it.

There may be occasions when government-owned or parastatal organizations particularly have to provide the local inhabitants with their basic requirements (for instance, fuelwood) gratis or at least at a lower price than the wood would fetch if it were sold on the open market. Services like these should be considered as a responsibility of the government toward the people.

2. TIMBER TYPES

A timber type in this context refers to timber filling certain requirements in quality and dimension. The number and kind of timber types in active use vary from one country, or even from one region, to another, depending in the long

term more on need and demand than on supply. Considered on a permanent basis, growing timber especially to satisfy an established need is much more profitable than trying to change the demand so that an existing supply can satisfy it.

Though there are innumerable different kinds of timber in the world there are some types which are in demand almost everywhere, and although their dimensions and even requirements of quality may vary from one country to another they can still be recognized as the same types. Timber used for similar purposes needs to be of approximately the same quality everywhere.

The most important types are the following:

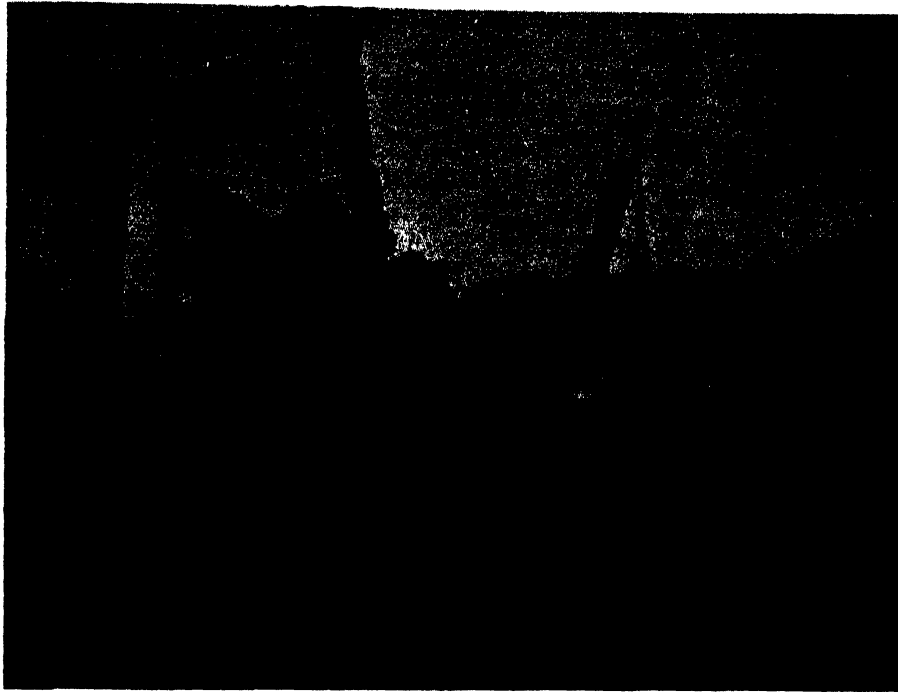
- large poles (telephone poles, etc.)
- sawlogs
- veneer logs
- stakes, sleepers, mine props
- small poles, building poles, roofing poles, ridge purlins
- pulpwood
- wood for particle board (chipboard)
- fuelwood
- special types.

The amount of waste from a harvested tree varies greatly in logging operations and is naturally highest if only timber of large dimensions is used. It is most profitable, as may be expected, to use as much of the tree as possible. In these days the classification of usefulness is rather vague; for instance, the leaves may be used as fodder or fertilizer.

The prices paid for different timber types vary widely, inducing the forest owner to try to produce mostly the more valuable kinds of timber. The order of prices is generally as follows (from the highest to the lowest):

- rare special timber mostly for decorative uses (masur wood, masured roots, gnarls). This kind of timber can be used for boxes, small furniture, sculptures and other art objects, etc. The main trouble with this type is that it is not usually regularly available. The demand is also at best irregular and as a rule very local, depending mainly on the presence of artists and artisans and on the demand for the finished products;
- relatively rare special timber, like wavy-grained wood or knotless pine logs. Timber like this is usually made into furniture and consequently the demand depends largely on fashion;
- timber types for which it would be unreasonably expensive to substitute some other material;
- large poles and sawlogs. Poles may fetch a slightly higher price depending on the quality requirements;
- stakes, sleepers, mine props;
- small poles and their variations;
- pulpwood;
- wood for particle board;
- fuelwood.

It is only natural that the relative value of different timber types should vary considerably from one region to another, depending on the demand and also on the balance between demand and supply. If several types are in demand at the same time - as is generally the case - it is rational to try to sell as much timber as possible for the more highly paid uses and the rest for less rewarding ones. This can usually be achieved by producing timber of good quality and at least medium size, and ensuring that harvesting is carried out with care. Normally that part of the tree with large dimensions is most valuable, provided it has no grave defects.



Trucks unloaded at the logyard by driving them up
a slight ramp and releasing the stakes.

The force of gravity helps in rolling
the logs off the platform (Border Timbers Ltd.)
(Photo: H. Seppänen)

3. QUALITY OF THE TIMBER

The quality required of various timber types is by and large defined by the needs and views of the user, in most cases the wood manufacturing industry. Requirements can be roughly divided into two classes, here called technical and structural. Both should be kept in mind when the harvesting of a forest stand is being planned and carried out.

3.1 Technical quality

In this paper the term "technical quality" is used to describe those characteristics which are set by two kinds of limits on the equipment handling and manufacturing the raw material (the logs): either its operational capacity or its profitable use. Both these considerations usually impose some demands as to the size of the logs and thus the matter of timber size is discussed under this heading.

3.1.1 Minimum size

The minimum size of various timber types does not depend so much on the operational capacity of the equipment as on its profitable use. If for instance sawlogs are small, so is the prime yield, and even if the small planks could be used in some way, most of the wood would fall into some relatively less valuable category or might even become waste. This is not economically sound; if the saw has to be operated it is obviously more desirable (economic) to use it to better purpose.

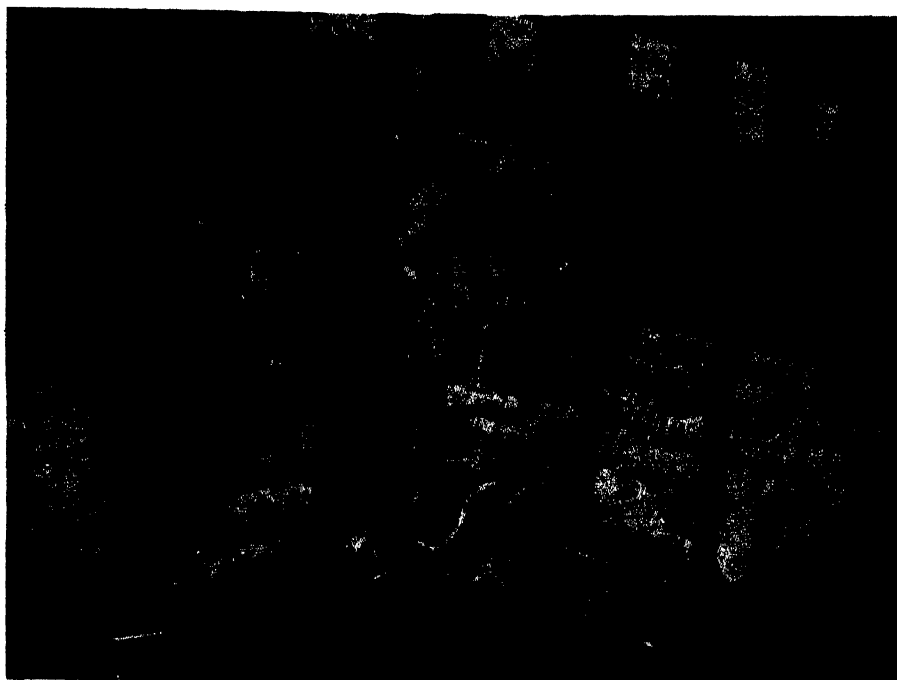
3.1.2 Maximum size

The equipment used in forest work and the wood manufacturing industry has mostly been designed for "normal sized" logs; there are limits to the maximum size of the logs they can handle. "Normal size" usually relates to the size of the trees in the country manufacturing the equipment; that is, an industrialized country, and thus the maximum limit is no great problem in the northern countries, for instance, where logs are not usually big enough for these limits to have practical effect. A few examples may illustrate this point:

- a tree may be so huge that it is impractical, uneconomic, difficult or even next to impossible to fell it. If logging is carried out with simple hand tools, it may be too time-consuming to fell the biggest hardwood trees. The cost of the actual felling may not be high, because labour costs in developing countries are usually low, but the other logging activities may prove to be very expensive. The felling of an oversized tree is also a safety hazard for the surrounding area and there is always the possibility that the tree will break when it hits the ground. The crosscutting of such a tree is always laborious, complicated and difficult. If processors are used in the logging, their operational capacity will considerably limit the dimension range;
- the transport equipment may not be able to carry the biggest logs. The road construction, especially in the humid tropics, may not be equal to very heavy loads. There may also be an official restriction on the length and weight of vehicles allowed on public roads. In most developing countries transport is often the bottleneck in the production chain and so it is usually uneconomic to lose time in struggling with the loading, transport (with inevitable breakdowns) and offloading of oversized logs. They may slow down the whole operation and at best cause rapid deterioration of roads and machinery;
- the machines of the wood industry enterprise - sawmill or pulpmill - may be unable to handle oversized timber. For instance, a very large log may not fit into the saw frame and thus be unusable although in every other respect of the highest quality;
- logs which are too long cannot be moved by conveyors so if they must be utilized extra work and special arrangements are needed. This is always expensive and in addition it is likely to slow production down.

3.2 Structural quality

In this context, the term "structural quality" is used to describe the quality of the raw material itself. Its importance varies greatly depending on the timber types. It is in the most valuable types that the strictest demands for quality are usually made. In this paper the rules on quality requirements have been taken mostly from those used in Finnish state forests. Although naturally they are not applicable to the world at large they are a good example of a logical set of rules where quality is considered to be of great importance.



Loading a grinder in a pulp and paper mill
(Mutare Board and Paper Mills) (Photo: H. Seppänen)

3.2.1 Structural quality of sawlogs

In a sawmill logs are usually sawn so that the centre yields thicker planks or barks while the sapwood is sawn into thinner boards. Especially in sawn timber of higher quality intended for export the principle is that the planks should be faultless while some minor defects may be allowed in the boards. Sawn wood meant for local consumption can usually be of lower grade and have more defects. It is fairly common in this case for there to be no difference in price between logs of the best grade and those just meeting the minimum requirements. It is advisable, however, to keep an eye on the quality; for in the long run a customer is not likely to accept logs of such poor quality that his sawing yield would be considerably diminished or of a uniformly low grade with a big percentage of rejects.

In large logs more defects (in number but not relatively) are permissible than in logs of small dimensions.

3.2.1.1 Tree species

The first prerequisite in logging for sawmill consumption is for the tree species actually to be suitable for sawing. This may sound like superfluous advice and does not concern plantations designated especially for use in a sawmill; but there have quite often been cases, especially in developing countries, where, for instance, plans have been made to use the products of bush clearing in a sawmill. The suitability of such species - if not already known - should be checked in advance to avoid unwelcome surprises. The wood might be too soft for the purpose and thus useless, but the characteristics really to watch out for are hardness and toughness. These properties are often caused by a high silicon content in the wood, which will quickly blunt the saw; in extreme cases it might prove impossible to saw the log at all. Pericopsis is a good case in point but by no means the only one.

3.2.1.2 Knots

Knots are the most common defect in sawlogs and the one by which the grade of the logs will in most cases be determined. When knots are sized they are measured directly against the length of the log and so that the measurements include both the heartwood and the sapwood in the knot. There are several different types of knot. Their maximum acceptable size - or whether they can be tolerated at all - varies according to their characteristics and their effect upon the sawing yield.

- (a) Fresh knots. These are on the surface of the wood, completely or partially attached to the surrounding material. Knots of this type are the least serious ones because they do not cause holes or considerable deterioration in the strength of the boards; consequently bigger ones of this type may be allowed than of the others.
- (b) Dead knots, dry knots. Dry knots are not on the surface of the wood but deeper, and they are not attached to the surrounding material. They may easily cause holes in the board, which lowers its grade. In spite of this, small dead knots are allowed in all grades of sawlogs.
- (c) Rotten knots, decayed knots. A knot is decayed if it is partly or completely rotten and soft rot extends within the knot into the wood. The knot may otherwise be fresh or dry. Rotten knots are not acceptable at all in sawlogs of better grade. In lower grades a certain amount may be tolerated. The general rule is that the maximum size of a rotten knot (even if only partly rotten) is half that of a fresh one.
- (d) Knot clusters, whorls. Branches are considered to form a cluster if there are at least three of them in the same whorl. In a knot cluster there may be one knot of maximum size; the others must be smaller.
- (e) Knot bumps. Knot bumps are formed by the growing over of knots which thus are relatively old and deep in the wood. They are not tolerated in timber of better grade because it has been observed that, especially in larger bumps, there is usually a big, often decayed, knot which would lower the quality or even cause rejection of the sawn timber. Smallish bumps may be allowed in sawlogs of lower grade.

If there are no knots of maximum size a larger number of smaller knots may be allowed in a log without reducing its grade.

3.2.1.3 Sweep, curve on one side

Restrictions on the amount of sweep in logs are based on the strong effect sweep has on the sawing yield, particularly in double-cut and band sawing. A very mild sweep can, however, be accepted even in sawlogs of the best grade. The amount acceptable depends on the diameter of the logs, the principle being that the normal amount of central yield must still be obtained. Twisted or corkscrew logs are not tolerated even in the lowest-grade sawlogs because they considerably affect yield and also quality.

3.2.1.4 Crooks

Crooked logs cannot be handled even by circular saws and much less by double-cut or band saws. Crooks of any kind are not tolerated in logs of the best grade, although in lower grades those that are slight enough to allow the normal central yield are permitted.

3.2.1.5 Rot

Rot is not permissible in sawlogs of any grade because it is not accepted in sawn timber.

3.2.1.6 Wet heart, watercore

Watercore is a term used of the wet patches occurring in the heartwood of coniferous trees.

- (a) Healthy or sound watercore. This type is allowed in sawlogs. It can be seen as smooth, firm patches on the cross-sectional surface of the logs.
- (b) Cracked watercore. In its effects on the quality of the sawn timber, cracked watercore can be compared to rot and consequently it is not tolerated in sawlogs. It can be seen in newly-felled logs as black-edged cracks following the lines of the annual rings.

3.2.1.7 Scars, wounds

- (a) Open scars, open wounds. Very small, sound, low wounds can be tolerated even in higher-grade sawlogs. The main consideration is that the normal amount of central yield must be obtainable from the log. In practice this means that wounds should be on one side of the log only and they must not reach the top diameter cylinder. Therefore they are not acceptable at or even near the top of the log. Rotten wounds are not accepted in any grade.
- (b) Covered scars, healed wounds. It is difficult to see the amount of damage in a healed wound, especially if it is not at the end of the log. Usually, covered scars are older and thus much deeper than open ones and consequently they are not allowed in sawlogs of the highest grade.

3.2.1.8 Heart checks, pith shakes

These defects can be seen as cracks in the heartwood. They occur in growing trees and thus must not be confused with cracks caused by the drying of the logs while stored. Heart checks lower the quality of the sawn timber and are therefore not tolerated in better-grade sawlogs.

In low-grade sawlogs some types of heart checks may be allowed on certain conditions:

- (a) A linear heart check which is visible at only one end of the log may be allowed if it does not exceed half the immediate diameter;
- (b) A star-shaped heart check visible at only one end of the log may be allowed if the combined length of the two longest forks does not exceed half the immediate diameter;
- (c) A linear or star-shaped heart check visible at both ends of the log may be allowed if in addition to the conditions mentioned above it is possible to get a 50-mm (2-inch) plank from the centre of the log. Otherwise the log must be rejected.

A spiral heart check is not tolerated because it would spoil the central yield. A ring or pith shake is a crack following the annual rings in a log. This defect is not accepted for the same reason.

If a heart check is large enough to reach the surface, the log must be rejected.

3.2.1.9 Resinous top of pine

Resinous top of pine is caused by a group of fungi (for instance, Cronartium peridermi-pini). The resinous wound - in spite of the name - is not always at the top of the tree. This defect is not tolerated in sawlogs of the best grade. In lower grades the affected part must nowhere exceed one half of the log circumference at that point and there must be at least three metres of sound wood in the log. If the damage caused by the fungus is extensive (if there are cracks in the wood or if the log has become deformed by the disease) the log must be rejected.

3.2.1.10 Other defects

- (a) Spiral growth. Pronounced spiral growth can adversely affect the strength of the sawn timber and is therefore not accepted in sawlogs. A mild spiral growth may be tolerated in lower-grade logs.
- (b) Compression wood. Compression wood is not allowed in sawlogs of the best grade. In lower grades a small amount may be tolerated.
- (c) Fork. Forks are not accepted because they would considerably diminish the sawing yield.
- (d) Circular cracks, circular healed wounds. These defects are not tolerated. Both would even at best affect the sawing yield badly and at worst cause the sawn timber to be rejected.
- (e) Vertical branches, upright limbs. These are caused through the tree's having lost its leading shoot some time in the past. In best-grade timber vertical branches are not included because they lower the quality considerably; in sawlogs of lower grade one such branch of medium dimensions may be allowed.

There are some defects which do not occur in growing trees but are caused by incorrect storage of the timber. Logs which have become discoloured or have worm-holes in them cannot be used for sawing, mainly because their appearance has been spoiled. Discolouring, for example, does not affect the strength of timber.

If a log has two maximal defects or certain combinations of defect - for instance, a crook and an open or healed wound at the butt end - it is not suitable for sawmill consumption. A log may, however, have a maximum-sized fresh knot and a maximum-sized dead knot and, if otherwise acceptable, still qualify as a sawlog.

3.2.2 Structural quality of large poles

The quality requirements for large poles are in many countries approximately the same as those for sawlogs. It is quite common, however, to find especially strict demands made with regard to the form of such poles - mainly to ensure that they are strong and durable.

- (a) Poles should be sound, in cross-section as nearly round as possible, and without any malformation;

- (b) They should preferably have no sweep at all (in export quality 10 percent of the logs may have a sweep of 1 cm - 3/8 inch - measured over the whole length of the log);
- (c) They should be free from rot.

Large knots, decayed knots or large knot bumps are not acceptable. A knot cluster may be tolerated if the individual knots are small. A small, sound, open wound may be allowed if it is shallow and if it has not caused any malformation of the log. Healed wounds are not accepted.

Less strict quality requirements may be made for poles for local consumption, depending on the regulations in that particular region. It is advisable to offer for export only poles of the highest quality.

3.2.3 Structural quality of veneer logs

Veneer logs, like sawlogs, need to be of relatively high-quality timber. The main difference is that while defects in sawlogs should be on or near the surface it is not so essential for a veneer log to have a faultless heart because this will remain unused in the core. It is the outer parts of a veneer log that must be perfect or nearly perfect.

3.2.3.1 Knots

Knots are unacceptable in best-grade veneer logs (though knots smaller than 5 mm are not counted). Some single knots are tolerated in logs of lower grade, the allowed size of fresh knots being bigger than that of dry or rotten ones. Small knot bumps are also allowed; but no bump is tolerated if inside it is a dry or decayed knot. Knot clusters (three knot bumps and/or knots within 20 cm of log length) are not accepted, nor are vertical branches. Both would cause grave defects in the veneer.

3.2.3.2 Sweep

Very mild sweep may be tolerated in a veneer log, usually only if it does not considerably diminish the amount of veneer which may be manufactured from the log.

3.2.3.3 Open or healed wounds

No wounds are allowed in best-grade logs. In lower grades small, sound wounds may be tolerated. No swelling must be visible around a healed wound. Rotten wounds are not acceptable.

3.2.3.4 Defects in heartwood

Hard discoloured heartwood or heart checks may be tolerated if they are so small or few that they will remain mostly in the core and consequently have no adverse effect on the amount or quality of the veneer.

3.2.3.5 Rot

Soft rot is not accepted in veneer logs because it is not accepted in veneer. It would also make peeling more difficult.

3.2.3.6 Surface cracks, twisting

Surface cracks and twisting or corkscrew stems are not allowed in veneer logs because they would greatly diminish the quantity of veneer to be manufactured from the logs. The same applies to sharp crooks in any part of the log.

No foreign objects are allowed to appear in the wood because being in most cases stone or metal, they would break the rotary veneer lathe.

If there are two different maximal defects in a veneer log, it is not suitable for veneer manufacturing. In addition to the general rules mentioned here there may be extra ones for veneer logs intended for special use.

3.2.4 Structural quality of stakes, sleepers, mine props, small poles

The quality requirements of these are in most cases less rigid than those of sawlogs, large poles and veneer logs. The main reason is that defects in their appearance are of small importance, as these types of timber are not meant to be used for decorative purposes. Consequently defects can be allowed if they will not affect the strength of the wood. These types of timber may, for instance, have large solitary fresh knots, but no whorls.

3.2.5 Structural quality of pulpwood

The quality requirements of pulpwood logs vary to some extent depending on the tree species used or on the method used in the process. The main requirements for all processes are, however, so similar that they can be described as valid for all.

3.2.5.1 Minimum diameter

Though not strictly a structural quality the minimum diameter of pulpwood may be mentioned here. Usually a pulpwood log must be at least 5 cm (2 inches) measured at the top under the bark. This minimum size requirement has been set because when a drum is used in the debarking process very thin logs tend to break easily, so material loss during debarking may be unreasonably high.

3.2.5.2 Rot in the heartwood

At both ends of the log rot may be visible for up to one half of the diameter, but the amount of sound wood visible should be at least that of the top diameter. With some tree species (mostly hardwood) rot is accepted only if it does not exceed one third of the immediate diameter. Rot affects negatively the amount of pulp obtainable from the raw material, the quality of the pulp will be inferior to that from entirely sound logs, and more than the normal amount of chemicals is needed; so the process becomes much more expensive.

3.2.5.3 Soot and coal

Soot and coal are not acceptable in pulpwood. They cannot be eliminated from the material at any stage of the process, not even in bleaching, and will therefore spoil its appearance so that it cannot be used for any purpose requiring high quality. This must be kept in mind especially where forest fires are common or where it is customary to burn regularly in the forest area for some reason such as controlled early burning. Logs containing soot or coal in

the wood itself (scorched bark does not matter) must be used for some other purpose. It is pointless to hope that this defect will not be noticed during inspection and measuring when the logs are delivered - for it will be all too obvious in the finished product and by that time it will have reduced the quality of the whole batch of pulp.

3.2.5.4 Crooks

Sharp crooks are not acceptable in pulpwood logs, partly because they would make the pulping process technically more difficult, but mainly because they cannot easily be completely debarked and any remaining bark makes bleaching the pulp more difficult and therefore more expensive. In some processes no bark can be included.

3.2.5.5 Storage time of pulpwood logs

Some pulp-manufacturing processes require the timber to be unseasoned.

3.2.6 Structural quality of chipboard and particle-board logs

The quality requirements for chipboard and particle-board logs are even less rigorous than those for pulpwood logs. Normally when there is demand for several kinds of timber types, chipboard and particle-board processes may well use the wood waste left over from other uses, for instance, sawing rejects and sawing waste. Foreign particles are not allowed in the material, however, because they would break the chipper, and the amount of dark bark (outer bark) may not exceed a certain percentage.

3.2.7 Structural quality of fuelwood

In industrialized countries there are quality requirements for the fuelwood on sale. In most developing countries, especially those where forests are scarce or unevenly distributed, almost the only prerequisite for fuelwood is that it will burn. It is also normal practice in developing countries for the users themselves to collect the fuelwood they need and thus it is not usually sold save in the form of charcoal.

If plantations are established for the sole purpose of providing the local inhabitants with the necessary fuel - either wood or more often charcoal - it is advisable to choose species suitable for that particular location, and with a high thermal value. Attention must also be paid to the necessity for the wood to make good charcoal.

3.2.8 Structural quality of special types of timber

The quality requirements of timber for special purposes will not be discussed in any detail here, because these types form a very small part of the whole timber production, though they might be of local importance. Suffice it to say that individual quality requirements may vary greatly depending on their uses. As mentioned earlier these types of wood are usually manufactured into decorative objects of one kind or another and therefore the material must be nearly or quite without defects which would diminish the appearance of the finished product. The most valuable types are often sold by weight.

4. BUCKING

When a tree is felled and debranched the next step is usually to crosscut or buck it. The operation in itself is simple enough: the stem is cut - as straight as possible against its length - into logs.

4.1 Bucking of sleepers, pulpwood logs, etc.

Sleepers and most pulpwood and similar logs are usually crosscut to a certain length. Sleepers conform to the distance between the rails. Where the others are concerned the main reason is to facilitate measurement of the piles and the transport.

When the length of the timber is fixed, bucking is fairly easy, and in the case of normal, sound logs almost mechanical. The only concern is to ensure that the logs fulfil the minimum quality requirements.

4.2 Bucking of sawlogs

In most cases sawlogs, large poles and veneer logs fetch a better price than pulpwood, for instance. In the following, the term "sawlog" is used for all these three types. The logical result of the difference in value is that when a tree is felled as much of it as possible is made into the more profitable types of timber. If the quality of the individual logs is not an essential feature - if the finished product will be used locally and the grade of the raw material has no effect on its price - then the crosscutting may be simple; the worker need only ensure that the minimum requirements in size and quality are met so that the log will not be rejected.

If the quality of the logs is important, close attention must be paid to the crosscutting. In this case it does not involve simply the action of cutting across the stem, but also, and possibly more importantly, a conscious decision on the exact places on the stem to crosscut. In a way bucking can be considered as the first processing operation of the sawmill or plywood industry because in the bucking it has been decided how much material of how high a quality the felled tree will yield. Careless or incompetent bucking may easily cause considerable loss in both the volume and the quality of sawn wood or veneer obtained from a certain amount of raw material; mistakes in bucking cannot be corrected later on without at least some loss of material.

4.2.1 Length

When the most valuable part of the tree is bucked three principal objects should always be kept in mind: the length, the quality and the commercial volume of the logs.

Commercial volume is that part of the log from which the sawing yield is obtained. The guiding principle is to maximize the commercial volume, that is, to get it as near the total volume as possible. Usually it is most profitable to make relatively long logs from slender trees which taper slowly, and short logs from conical, quickly tapering trees. Even here the needs of the customer must be kept in mind. Big customers usually accept a normal length range of logs, but the principal need of a small customer might be for short logs (because he needs short sawn timber for some specific purpose and his whole operating capacity is used to fill that order). Then it would be uneconomic and shortsighted stubbornly to make long logs which must then be shortened to suit his need.

It is usual for only a certain percentage of very short logs (so-called special minimum length) to be accepted and then only when particular conditions have made it unavoidable. It is usually for the following reasons:

- (a) A longer log would be rejected because its defects would exceed the allowed maximum; for instance, it would have too pronounced a sweep;
- (b) The quality of the stem changes so radically at some point that to make the log longer would mean having it fall into a much lower category;
- (c) To make the log longer would involve including a grave defect at its top.

In other cases logs should meet at least the normal minimum length.

Very long logs of the maximum length or near it should also be avoided because they usually mean a smaller commercial volume than could be got from shorter logs. Long logs are to be avoided especially if the diameter of the tree is small.

4.2.2 Quality

The grade of a sawlog is in a sense determined by its worst defect. Thus, if there is a place in the stem where its quality deteriorates noticeably, bucking must be carried out so that the good part of the stem (usually the butt end) will be made into high-quality logs and the rest of it into lower-grade ones. At the same time the required minimum length of acceptable logs must be borne in mind. It is obviously wiser to lower the grade of a log than to have it rejected altogether because of its shortness. It must also be remembered during bucking that defects are always considered more serious when they occur at the top of the log or near it, because there they affect the sawing yield much more than at the butt end.

If the stem is sound and normal in shape, bucking is fairly easy: the worker just needs to notice the length, diameter and taper. When there are considerable irregularities in the stem, bucking must be carried out so that they are as far as possible eliminated or at least their effect is minimized; and this must be done without causing undue loss of material.

4.2.2.1 Handling of serious defects - practical examples

The most common defects in sawlogs and veneer logs have already been described in Sections 3.2.1 and 3.2.3. The aim of this section is to show how to avoid lowering the grade of a log or having it rejected altogether. This can be achieved by judicious bucking of the stem.

- (a) Vertical branch, upright limb. One not too big vertical branch may be accepted in lower-grade sawlogs, but not in those of the best grade. To keep the quality of the butt log high it is advisable to crosscut the stem just below the vertical branch.
- (b) Sweep. When a tree has sweep it should be crosscut into short logs with the crosscutting point at the bottom of the sweep. This will minimize the defect which otherwise would lower the grade or, if left in a long log, might even cause the log to be rejected.

- (c) Crooks. Mild crooks may be allowed in lower-grade logs if crosscutting will place the crook at the butt end. Sharp crooks are not accepted and must be cut off altogether. Crooks with an open or healed wound (which occur usually at the butt of the tree) are not tolerated and must be cut off; preferably so that the faulty part is not totally wasted but can be used for some type of timber with less rigorous quality requirements.
- (d) Fructification (conk), wounds with rot. Fructifications are not acceptable in a sawlog because they are indications of widespread rot in the wood. The stem must be crosscut as near the conk as possible. If this means that the butt log would fall short of the minimum length, it is better to relegate that part of the tree to pulpwood. Further offcuttings must then be made in both directions till no rot remains. If rot and a growth or growths can be seen at both ends of a stem it is obvious that the rot has spread everywhere and the stem cannot be accepted for either sawmill consumption or veneer manufacturing.

Similarly, wounds with rot are not tolerated in mid-stem. That part of the stem must be cut off, preferably so that the rest can still be made into sawlogs. Good care must be taken to ensure that no rot remains in the logs which would then be rejected.

- (e) Fork. If a stem is forked, it should be crosscut below the fork at a point where the shape of the stem has not yet been affected by it. No bark should remain at the bottom of the cut. The part with the fork must be cut off altogether as a fork is not acceptable even for pulpwood (see Section 3.2.5.4).
- (f) Circular wounds or circular cracks. An open circular wound which is sound may be accepted in sawlogs of lower quality if the wound is completely outside the top cylinder (not at or near the top of the log). If the defect is rather near the butt it is possible to minimize its effect by making the log fairly long. Healed circular wounds are not accepted, nor are circular cracks (ring shakes), so the parts of the stem containing these may be made into pulpwood.

5. MEASURING

The unit normally used in the timber trade is the solid volume of timber with bark. The examples used in this chapter are again mostly from Finland.

5.1 Measuring large timber

Sawlogs, veneer logs, large poles and sleepers are usually measured individually. Methods may vary depending on the type of timber and on the tree species. There are conversion tables for every type of timber; they are easy to use when the length and the diameter of the logs are known.

5.1.1 Length

The length of a log is measured at the shortest distance between crosscutting points.

5.1.1.1 Sawlogs

Depending on the agreements made, sawlogs can be crosscut to exact lengths or they may be measured by eye.

- (a) Exact or fixed length means that the logs are measured in decimetres (dm). The shortest acceptable log measures 31 dm and from here on, the length classes proceed at 3-dm intervals (34, 37, 40...). Deviation may be at most ± 3 cm.
- (b) When logs are bucked according to measurement by eye, the minimum length is the same, 31 dm, and the principle of the classes is also the same (34, 37 ...). The length of the log is defined by rounding it off to the nearest class midpoint.

5.1.1.2 Veneer logs

The length of veneer logs can be measured like that of sawlogs.

5.1.1.3 Large poles

The length of large poles is measured in full metres, the shortest acceptable pole being 7 m.

5.1.1.4 Sleepers

Sleepers are of a fixed length (in Finland 2.75 m).

5.1.2 Diameter

Ways of measuring the diameter of large timber vary according to the type of timber. This is not done to cause confusion as one may sometimes suspect, but because research has proved that with different types different ways must be used to get the most accurate results.

5.1.2.1 Sawlogs

The diameter of a sawlog is measured in centimetres at the top of the log under the bark, rounding the figure off to the nearest odd number. If there is a knot bump or some other swelling right at the top of the log, the diameter is measured at the nearest point unaffected by the swelling. If the log is markedly oval it must be cross-measured and the average taken.

5.1.2.2 Veneer logs

The rules are the same as for sawlogs but the bark is included.

5.1.2.3 Large poles

The diameter is measured at the middle of the pole, with the bark included.

5.1.2.4 Sleepers

The diameter is measured like that of sawlogs.

5.2 Measuring of some other types of timber

Most of the other timber types are of a fixed length which makes their measuring easier. They are not usually measured one by one but in piles, stacks, etc.

5.2.1 Measuring piled wood

The length of the pile is measured in decimetres at both sides of the pile and its height is measured in centimetres at regular intervals. The length of the timber would already be known, so using conversion tables and taking into account various factors (debranching and branchiness, general amount of crooks, density of piling, etc.) the solid volume of timber may be calculated.

5.2.2 Other measuring methods

All the methods mentioned above can be used in the forest. There are some other methods more suitable for measuring timber in forest industry enterprises but they are not within the scope of this paper. It may just be mentioned that the volume of timber may be found by weighing it or measuring its density or immersing it. Some types of timber (sawdust, chipped wood) are measured using their loose volume.

6. LOGGING METHODS

There are several ways to log a forest stand - after all, only the felling of the trees must necessarily be done in the forest. All other parts of the work can be done somewhere else if that is more practical or more profitable. It is not the purpose of this paper to describe the different methods in any detail but to point out the demands they make on the training of workers in the bucking, measuring and grading of logs.

6.1 Assortment system (shortwood logging)

In shortwood logging the felled and debranched tree is made into timber assortments in the cutting strip, before transport in the terrain. An advantage of this system is that felling can be kept apart from transport. The assortment system is practical, but the forest workers must be well-trained and preferably have previous experience. In this system it is they who carry out the bucking and they must therefore be well aware of the rules.

6.2 Long-length system

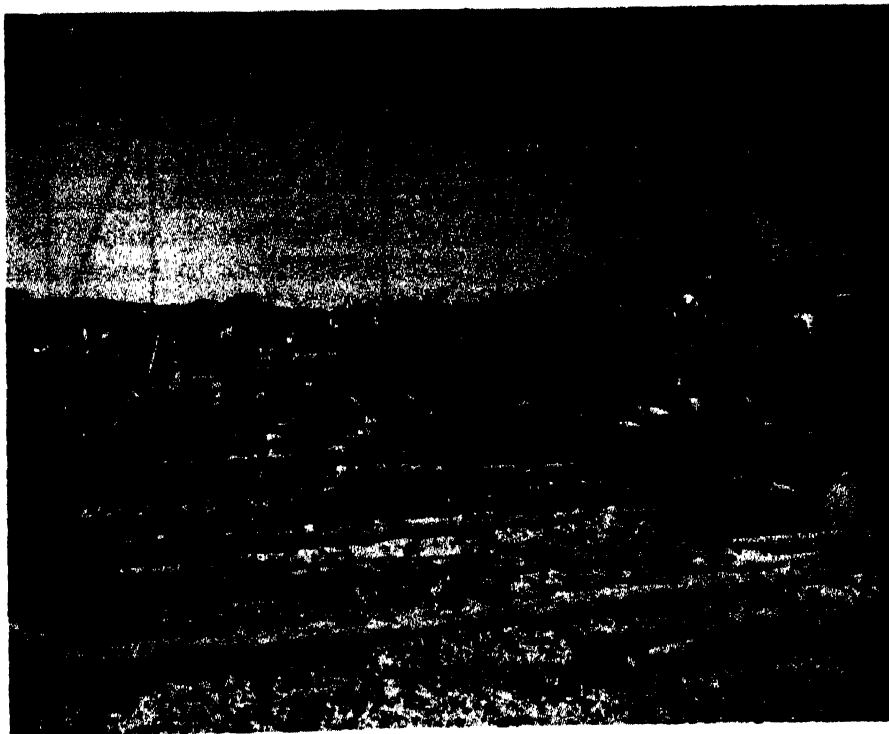
In this system the trees are felled and debranched in the strip. Smaller stems are crosscut at the minimum diameter, bigger ones are made into logs usually 4-6 m long. These are taken to roadside landings using skidders or forwarders. They are converted either then or after transport by truck to the logging terminals. The advantage of this system is that not all the forest workers doing the felling need be well trained in bucking; the people working at the landings and terminals are usually fewer in number and thus it is easier to get them trained. The disadvantage is the difficulty in measuring the timber.

6.3 Whole-stem system

In the whole-stem system the trees are felled and debranched in the strip and after that skidded or forwarded to the roadside landings where they are converted. This system has mostly been used with heavy machinery in clearfellings but it is also possible with agricultural tractors. The advantage is the same as in the long-length system. The disadvantage is that it needs a large space.

6.4 Whole-tree system

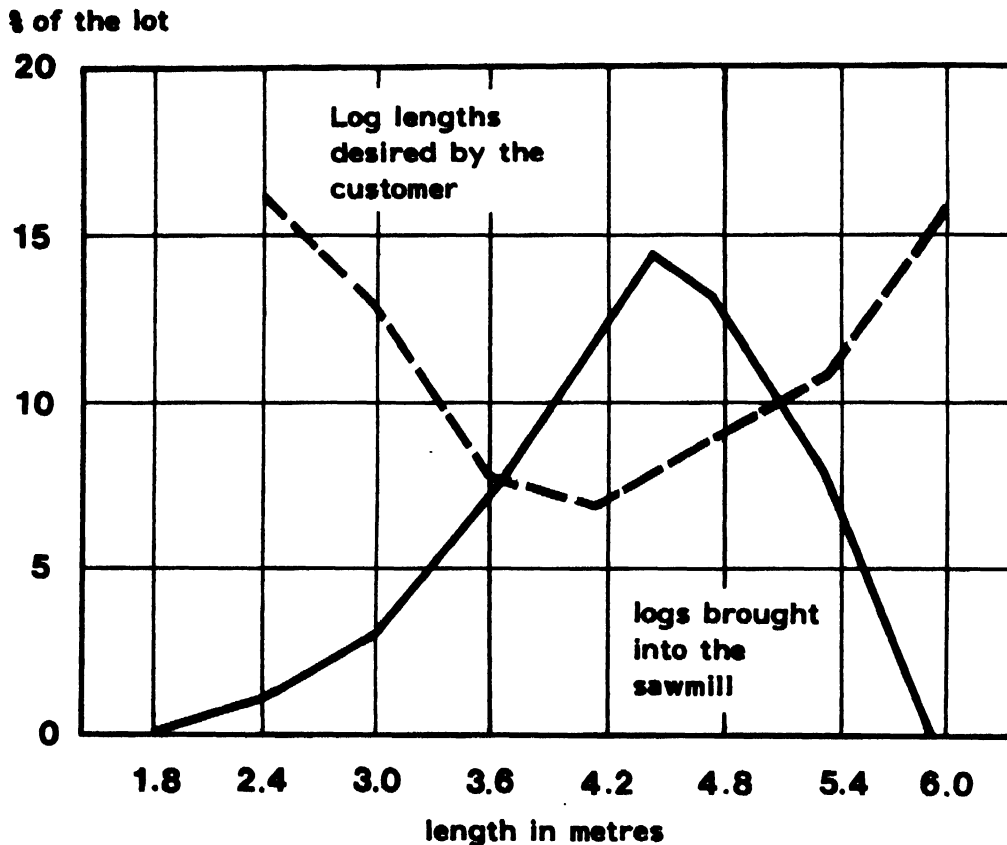
It is possible just to fell trees in the strip and take them without debranching or crosscutting to the landing or even to the logging terminal. Almost the only reason for doing this on a large scale would be to use the branches at their destination - for instance, if the wood manufacturing industry used the whole tree and not only the trunk in its processes. If the trees are small this method does not necessarily require much machinery. If they are big only special equipment can be used. The advantage of the system is the same as in the two previous systems; the disadvantages are the big space needed and the amount of waste if the branches cannot be used for anything.



Logs crosscut at the logyard by chainsaw into
short log lengths and rolled by gravity
to a feed chain for the mill
(Forestry Commission, Erin Estate) (Photo: H. Seppänen)

7. CONCLUSIONS

To make the most of a forest stand, silvicultural methods can be used to improve its quality, workers can be trained to do the logging work expertly. But these will not in themselves lead to the desired result; for it must be ascertained what the customer really wants - and very often this is not the same as what the forest owner could most easily supply. To illustrate circumstances which should definitely be improved this presentation finishes with a simple diagram showing the situation in some sawmills:



THE LENGTH OF LOGS BROUGHT TO SOME SAWMILLS COMPARED
WITH THE LENGTH THEY DESIRED

It would not be impossible in this case to meet the wishes of the customer
- it must just be made to happen.

INTRODUCTION TO TIME AND WORK STUDIES IN WOOD HARVESTING

by

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1. GENERAL

Productivity is a favourite word in modern vocabularies. For some time it has not been considered sufficient just to work; in the field of production definite knowledge about ways of working and of improving the effectiveness of work is needed.

Work science is the branch of knowledge which deals with work and productivity and the measurement of these. It is the aim of work science to give information about:

- (a) the work itself;
- (b) the methods of work;
- (c) equipment used in the work;
- (d) the role, behaviour and actions of a worker engaged in the work.

Work science has at its disposal several means of realizing the aims mentioned above. It is the intention of this paper to give an introduction to those means which have proved suitable for the conditions in forestry work and especially in wood harvesting. It should be remembered that while the working conditions in industry may be stable, those in forestry vary a great deal and cannot be influenced or controlled for the sake of scientific research. Forest conditions, terrain, climatic conditions and season are some of the factors which affect forest work and make it necessary to change or modulate the research methods used.

2. THE DEFINITION AND AIMS OF WORK STUDY

Work study is one of the most important techniques in work science. It may be defined as a generic term for those techniques, particularly method study and work measurement, which are used in the systematic examination of human work in all its contexts, and all the factors affecting its efficiency and economy, in order to effect improvement.

It includes the social, psychological and physiological aspects of a worker at work, as well as the technical working conditions. Its purpose is to develop both existing methods and new and better ones; to gain information and knowledge on the time consumption and performance of work; and to improve working conditions.

It is thus a mistake to regard work study as only a means of improving efficiency and productivity. If this attitude is adopted and all effort is concentrated on improving the economic side, the results of the study may cause a worsening of working conditions, and job satisfaction and motivation will suffer.

It must be kept in mind that work study is not the answer to every problem. It can show where the mistakes in work organization and in the working process itself lie and it can also provide valid ideas and guidelines. Nevertheless, it is not an end in itself; and it cannot say what will be done, only suggest what should be done. It remains the duty of a manager to decide what actually to do and how to improve an existing situation.

In big enterprises it is usually considered profitable to have a permanent work-study department, or at least permanent, specialized staff, to carry out studies in relevant fields. The department or unit is in a way paying for itself by improving production and making direct savings for the enterprise. Enterprises may also hire a consultant to carry out studies for them. In both cases the staff involved are employed solely for this purpose and are not in a "line" position.

Based mainly on such examples, people's attitude to work study may be that it is something to be slightly in awe of, a highly skilled job which only thoroughly trained specialists can do. This is far from the truth. In forestry, for example, all the managers can easily be trained to carry out simple work studies - and they should do so, because as a result it would be much easier to plan the profitable use of machinery and equipment as well as of manual labour.

3. PLANNING A WORK STUDY

Like every other well-conducted activity in an enterprise, work study needs careful preliminary planning. It is often easy to see which part of the production needs speedy improvement - it may be that the machine operations are not well organized and so the machines stand idle for much of the time though there is plenty of work for them. If a work study is launched without any preliminary planning to solve the problem and improve the situation, it is likely that much time and energy will be wasted. The benefit may indeed be only marginal because the most obvious problem is really the outcome of an underlying one which should have been the object of the study.

When work studies are planned the priorities should first be established. This is especially important if the available resources are limited, as is mostly the case in developing countries. In this context, it should be emphasized that work studies involving the heavy machinery used in wood harvesting should have high priority because their capital costs are great and therefore they should be used as effectively as possible. Even a small (in percentage) improvement in the productivity of these machines will probably be financially more profitable than a much bigger one (again, in percentage) in the productivity of manual work. At all times the resources available or likely to be obtained for the project need to be kept in mind so that planning is not on too large a scale.

When a project has been decided upon, a definite plan must be drawn up. It is a grave mistake to believe one is capable of keeping the complete details of a plan in one's head and that there is no need to put it on paper.

The plan should include information on the following:

- (a) the object of the study and the possible benefits to be derived from application of the results;

- (b) the scope of the study;
- (c) the time needed for the field work, for handling the material and for preparation of the results, and the date when the results should be available;
- (d) estimated costs of the project, including staff time;
- (e) the people involved in the study and also those whose task will be to carry out the suggested improvements.

It may sometimes be wise to conduct a pilot study to get a better idea of the time and work requirements of the study - especially advisable when it is to be conducted with heavy machinery.

When the decision is taken on the staff to carry out a particular study, it must be remembered that objectivity is of prime importance. Many of the people who are permanently employed to do work studies also do a lot of the work on developing methods and other matters on which studies are made. No staff should be allowed to conduct a work study on the methods or working systems they themselves have developed, being personally involved and likely to be partial to the methods of their own invention. It is quite likely that they themselves do not realize that their approach is biased, and honestly believe in their conclusions; nevertheless the results are not dependable.

When a work study is properly planned, with an eye to the practical side, the actual work should be able to proceed with a minimum of unexpected detail and confusion.

4. CARRYING OUT A WORK STUDY

Work studies may use different techniques, but those most commonly met in forestry are method study and certain variations of time measurement.

4.1 Method study

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs. The objects of method study are:

- (a) the improvement of processes and procedures;
- (b) economy in human effort and the reduction of unnecessary fatigue;
- (c) improvement in the use of machines and manpower.

There are some other objects, but they are not easily applicable to work in the forest and are therefore not mentioned in this context.

There are several techniques suitable for method study, but whichever is used, the same basic procedure must be carefully followed. The correct steps in any method study are the following:

- (a) Select the work to be studied;

- (b) Record all the relevant facts about the present method by direct observation. There are many ways of recording these. In some cases they can simply be written down, but this can often prove to be impractical as a detailed description of even a short sequence of events can take a long time. Commonly used means are charts and diagrams; there are several standard types of both. It might in some cases be practical to film the working method and thus repeat the performance for close study;
- (c) Examine the relevant facts critically and in ordered sequence, using the techniques best suited to the purpose. This means that all the elements recorded will have to be examined critically and logically to see whether they really are essential to the operation and, if they are, whether they are used in the best possible way (optimal time, optimal place, appropriate person);
- (d) Develop the most practical, economic and effective method, having due regard to all contingent circumstances. When a new method is being developed it is essential to know the aim of the work and also where, when, by whom and how it should be done. The proposed new method must be recorded and compared with the old one to see what has been improved. This can be done using flow process charts;
- (e) Define the new method so that it can always be identified. The usual way of doing this is to prepare a written standard-practice description;
- (f) Install the method as a standard practice. It is normal procedure to try out the new method first on a smaller scale; it is easier to do the final polishing of the system this way and only then allow it to be used on a wider scale. It is also easier to train workers in small groups to use the new method;
- (g) Maintain the standard practice by regular routine checks. It is all very well to develop new methods of carrying out a job, but new methods are useful only if they are also maintained. Workers have a tendency to go back to the well-known old way of doing work, if they are not frequently checked. At the beginning the new way seem an interesting novelty, but after a while the old way might feel more comfortable because it has already been adopted as routine.

4.2 Work measurement

Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance. Work measurement is concerned with investigating, reducing and subsequently eliminating ineffective time, during which for one reason or another no effective work is performed. By using work measurement it is possible to compare the efficiency of alternative methods and to prepare standard timetables and output guides for different activities.

As mentioned before, work in the forest is more variable than that in industry. There are conditions which cannot be controlled and which make it more difficult to use work measurement as a way of getting reliable information by means of which the corresponding factors in different methods may be compared. A simple example will illuminate the difficulties: a work method may usually be quick but measured on a cold, rainy day the uncontrollable extraneous conditions may cause it to appear less so.

As in method study there is a basic procedure in work measurement, as follows:

- (a) Select the work to be studied;
- (b) Record all the relevant data on the circumstances in which the work is carried out, the methods and the elements of activity in them;
- (c) Examine the recorded data and the detailed breakdown critically to ensure that the most effective method and motions are being used and that unproductive and foreign elements are separated from productive elements;
- (d) Measure the quantity of work involved in each element, in terms of time, using the appropriate work measurement techniques;
- (e) Compile the standard time for the operation, which in the case of a stopwatch time study will include time allowances to cover relaxation, personal needs, etc.;
- (f) Define precisely the series of activities and method of operation for which the time has been compiled and issue the time as standard for the activities and methods specified.

In this paper only those techniques which have been and are presently used in forestry will be given closer inspection.

4.2.1 Work sampling (activity sampling)

Work sampling is a method of finding the percentage occurrence of a certain activity by statistical sampling and random observations. Instead of observing continuously all the activities in a certain area - which would in most cases be impossible and at best expensive - it is possible to make a number of instantaneous, "at a glance" observations, for instance, to see how many machines are working at any moment. This technique may be used, for example, in felling or in machine operations. When the sample size is large enough and the observations are indeed made at random intervals it is quite likely that this method will show the right proportions of time spent in various occupations or in inactivity.

Sampling is based mainly on probability. In practice this means that the larger the sample the bigger the probability of the results being accurate. Before an activity sampling is made its size should be chosen according to the degree of accuracy wanted. Distribution curves can be used to obtain the number of samples needed for an acceptable level of accuracy. The times when observations are made must be chosen at random and for this purpose it is convenient to use tables of random numbers.

Before actual observations are made it must also be decided how detailed the study should be. Where a machine is concerned the easiest way is to observe whether it is working or standing idle; more detailed studies show each work activity and each reason for inactivity.

The observations themselves are easy to make and no great skill is needed, though care must be taken to record the time exactly. The observations can be noted on a simple record sheet by simply making a stroke in the right place.

4.2.2 Time study

Time study is a work measurement technique for recording the times and rates of working for the elements in a specified job performed under specific conditions, and for analysing the data so as to obtain the time needed to carry out the job at a defined level of performance - or in simpler terms it is a form of work study aimed at assessing time consumption.

4.2.2.1 Basic time study equipment

The following equipment is needed:

- (a) A stopwatch which can be either of the flyback or non-flyback type. Sometimes a split-hand stopwatch is used;
- (b) A clip-board on which to place the record forms;
- (c) The forms. There are countless types of these in use; experts usually have their own preferences.

It is also useful to have a small calculator, a reliable clock and various measuring instruments in the office.

In most books of reference this basic equipment is described as necessary, but it should be pointed out that if nothing else is available, it is perfectly possible to carry out a simple time study with an ordinary wristwatch and a sheet of plain paper appropriately ruled.

In more sophisticated time studies, other timing devices can be used. They are not much used in forestry and will not be described here.

4.2.2.2 Reasons for a time study

Some possible reasons are the following:

- (a) The job in question is a new one;
- (b) A change in the method of working has been made and a new time standard is required;
- (c) A time standard should be revised;
- (d) A particular operation appears to be a bottleneck holding up all the subsequent operations and possibly previous ones (for instance, terrain transport);
- (e) A piece of equipment appears to be idle for an excessive time or its output is low;
- (f) The efficiency of two proposed methods needs to be compared;
- (g) The cost of a particular job appears to be too high.

If the purpose of the study is to set some performance standards, a method study should be carried out first to ensure that the work is being done in the most satisfactory way.

4.2.2.3 Stages in a time study

When it has been decided what work should be measured, the time study can usually be conducted in eight stages:

- (1) Obtaining and recording all the necessary information about the job. This is done by direct observation;
- (2) Recording a complete description of the method;
- (3) Examining detailed elements of work to ensure that the most effective method is used, and determining the sample size;
- (4) Measuring with a stopwatch and recording the time taken to perform each element of the operation. This can be done either by cumulative (continuous) timing where the watch is running continuously and the time elements are the difference between two recorded times, or by flyback (repetitive) timing where the time is put back to zero at the end of each element;
- (5) Assessing the effective speed of working. People work at different speeds and the speed of the same person varies according to the time of the day, etc. Such differences are allowed for by rating; an average worker rates 100; those working faster rate more highly while slow workers rate lower;
- (6) Extending the observed times to basic times. This is done by multiplying the observed time by the observed rating and dividing it by the standard rating (100);
- (7) Determining the allowances made over and above the basic time for the operation. This is perhaps the most difficult part of a work study. The time taken to do a job is not just the sum of direct and indirect work, for an amount of rest must be included. This cannot be determined simply by using a certain percentage of the other times or some similar arrangement, because it varies depending on the individual, on the work in question, and on the environment. All these factors should be judiciously considered;
- (8) Determining the standard time for the operation. Standard time is the total time in which a job should be completed at standard performance. It consists of direct work, indirect work and rest.

4.2.2.4 Scandinavian time studies

In Scandinavian countries time studies in forest work are conducted using a method called comparative time study. The principal difference of this system is that there is no rating. Performance rating is seen as based on subjective estimates; it is difficult to carry out for forest work and cannot be approved as a scientifically acceptable method. For these reasons performance rating is used only in cases where special considerations make it necessary.

In practice this means that when time studies are carried out to compare two different work methods, the Scandinavian system has the same worker use both methods in turn. This eliminates the need for rating and simplifies the system. The study can be done with smaller samples and is thus cheaper and quicker.

5. DIVISION OF TIME IN FORESTRY WORK SCIENCE

Some definitions of the vocabulary used in work and time studies are given below.

5.1 Direct time

Direct times are usually classified by their relation to various work cycles (season, work place, work day, work object). They include:

- (a) calendar time, which means all available time in a certain period;
- (b) total working time, which is time required directly or indirectly to carry out a certain task;
- (c) work-place time, which is time spent performing a task at a working place;
- (d) effective time, which is time required to perform a specified work element. It can be divided into main time and by-time.

5.2 Indirect times

Indirect times are divided into fixed and variable times. Fixed times include:

- (a) moving time, which is the time of moving machines, equipment and workers from one working place to another;
- (b) change-over time, which is the time used for preparation of machines, equipment and working-place conditions when beginning and after finishing a certain task;
- (c) the fixed by-time of the effective time.

Variable indirect times include:

- (a) unutilized time, which is that part of calendar time which cannot be referred to the total working time;
- (b) repair time, that part of repair and maintenance which has to be carried out outside the normal work-place time;
- (c) interruption time, during which no work is carried out because of external conditions.
- (d) travelling time;
- (e) meal time;
- (f) delay time, when an interruption occurs to break the continuity of a performance. This can be divided into unavoidable and avoidable delay;
- (g) variable by-time of the effective time.

6. CONCLUSIONS

Work and time studies are an important means of development in forestry work, but it cannot be too strongly stressed that they are not an end in themselves; they have to be followed by action. A proper study report must include - besides the results - recommendations for the improvement of work, and it is the duty of the management to see that these recommendations are put into practice and maintained.

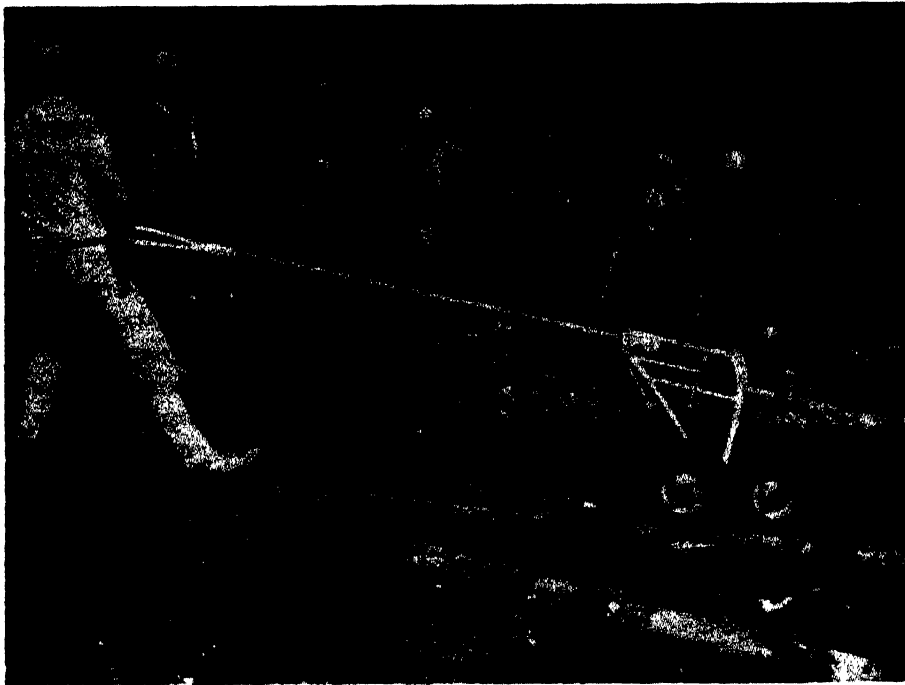
A final word of warning: it is natural and even practical to use the results of work studies carried out by some other agency, if they seem applicable to the situation. The results of work studies done by the manufacturers of certain machines or equipment should, however, be taken with a pinch of salt. No manufacturer with any business sense would show results which are less than favourable to his equipment, so the suspicion arises that the approach has not been objective. For instance, the working conditions might have been chosen so that they favour the product of that manufacturer. Work studies should always be carried out in normal conditions, if such can be thought to prevail in forestry; otherwise the results will be distorted and unreliable.

REFERENCES

ILO Introduction to Work Study, Geneva.
1981

NSR Nordisk avtale om skoglig arbeidsstudienomenklatur.
1978

Oakley, J.S. The role of work study in the application of technology
1974 in forestry, with special reference to developing countries. A
seminar report.



A manually-pulled sulky with four-wheeled bogie.
The sulky appears to be efficient in manual skidding
in plantation forests in flat and undulating terrain
(Mutare Board and Paper Mills) (Photo: H. Seppänen)

VOCATIONAL TRAINING, SAFETY, HEALTH AND ERGONOMICS IN FORESTRY WORK

by

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1. INTRODUCTION

Articles on safety, health or ergonomics in forestry frequently start with the remark that it is hazardous and dangerous work. This is often true, but not always. Forestry work also has many advantages to be weighed against the disadvantages, and some of the disadvantages are avoidable.

Properly trained management and workers are a prerequisite for any productive, cost-competitive and safe forest work. For example, in Finland where 90 percent of tree-felling is with chainsaws, there are fewer accidents in forestry work than in construction or mining, a result achieved by active training in work safety, health and ergonomics, at all organizational levels. It followed upon extensive research and an approach to vocational training and ergonomic improvements in which these are regarded as investments rather than as costs. They are investments which over a short period can be recovered in reduced costs of occupational illnesses and accidents.

Compared with industrialized countries, the present situation in the fields of vocational training, safety, health and ergonomics is very different in developing countries. One reason is that the latter have often plunged into quite modern technologies without taking the necessary steps forward through small changes in the whole society (gradual increase in wealth, improved infrastructure, social legislation, etc.).

In developing countries insufficiently trained workers are often put into positions which they cannot manage. It is common, for example, for a tractor driver to get only short on-the-job training before starting his work, so he cannot grasp all its concomitants and implications (the consequences of speeding, overloading, uneconomic driving, inadequate machine maintenance, etc.). The chainsaw operator has likewise often received only brief on-the-job training in handling the saw, and knows little about the safety hazards, correct working methods, and so on; but the chainsaw, with the machet, is by far the most important source of serious accidents in forest work.

These weaknesses in combination with "normal" problems of the tropics such as high temperature and humidity, low salaries, poor nutrition, inadequate living conditions, diseases, are the major factors to be considered when forestry work is developed. The aim is to combine high production and a competitive cost structure with good working conditions that satisfy the forest workers.

2. THE MEANING OF VOCATIONAL TRAINING, SAFETY, HEALTH AND ERGONOMICS

2.1 Vocational training

Vocational training enables the worker to carry out his duties effectively, economically and safely. It clearly provides an essential part of forest workers' job satisfaction. Often, however, there is widespread belief in

developing countries that appropriate technologies are so simple that workers do not need training or that only short instruction is required; although the training of operators for complicated machines like trucks is considered necessary.

If this attitude cannot be overcome, there is little hope of introducing labour-efficient and cost-competitive technologies into forest operations. The management of a forestry company will also accept an unnecessarily heavy human responsibility, if it employs labour receiving only brief on-the-spot instruction before starting work. The accident rate for untrained or poorly trained workers is very high compared with well-trained workers.

All forestry enterprises must agree that the aim of vocational training is to secure skilled, qualified workers in order to increase output and reduce costs, accidents, and waste of raw material. It was found, for example, that the productivity of trained workers improved nearly 25 percent and that there was a reduction in waste of timber of about 8 percent when improved logging methods were introduced.

Trained workers also have higher incomes and more nutritive food intake in their households than untrained workers.

Note: The recommended durations and contents of syllabi for vocational training are available in several publications by ILO, FAO and FTP. These organizations will advise on planning, design and implementation of vocational training activities.

2.2. Safety

Safety in this context refers to conditions of work where workers are prevented from being disabled or killed in an occupational accident.

In central Europe, on average one out of five permanently employed forest workers has one accident a year, and one out of 50 workers who are employed in the forest for their entire working life dies as a result of an occupational accident (Strehlke, 1979). According to one study, the risk of an occupational accident was ten times higher in some tropical countries in Asia and West Africa than in industrialized countries. The risk of a fatal accident was also ten times higher (Bostrand, 1983).

Accident prevention should receive high priority in any business simply because people are involved; the avoidance of human misery is reason enough to pursue an aggressive accident-prevention programme. People are not the only reason, however. In occupational accidents the company suffers heavy economic losses, the morale of employees goes down, and public relations are hampered.

2.3 Health

Health in this context means the absence of occupational illnesses. The health situation in the tropics is generally quite different from that in industrialized countries. Malaria, in particular, which is again on the increase, causes a lot of harm; it is not an occupational disease but it weakens people who then become more easily exposed to occupational illnesses.

"Normal" occupational illnesses in forestry work include back problems (from all heavy work) and reduced hearing (from chainsaw work and tractor driving).

Because of improved accident-prevention programmes in industrialized countries, occupational illnesses are becoming more expensive than occupational accidents.

2.4 Ergonomics

Ergonomics is a science which studies the relationships among the work environment, the work itself, and the workers. Its aim is to find practical ways, by designing the work, the work environment, and the machines and tools according to human characteristics, to help the workers maintain their health and ability to work effectively and enjoy good job-satisfaction (Harstela, 1983).

Another definition states that ergonomics is to "fit the job to the worker and optimize the man-task-environment system in view of the workers' health, well-being and efficiency" (Bostrand, 1983).

It is often assumed that through ergonomics efficiency will go down and costs will rise. This is not true. Ergonomic measures will mostly improve efficiency, reduce costs, and improve job-satisfaction.

3. FORESTRY ENVIRONMENT IN THE TROPICS

To influence environmental factors is often difficult if not impossible. These should, however, be taken into consideration when safe working techniques or worksite arrangements are being planned.

The working environment varies considerably from indigenous forests with large-diameter trees to dense plantations and even bushland; from rain forest to savannah; from mountains to lowlands; from areas with heavy rain and a long rainy season to near-desert. The working techniques and worksite arrangements vary accordingly and have to be planned for each place individually.

4. WORKING AND LIVING CONDITIONS OF FOREST WORKERS

The working capacity of workers in the tropics is frequently rather low. The so-called "economic cycle of diseases" illustrates the situation (Harstela, 1983):

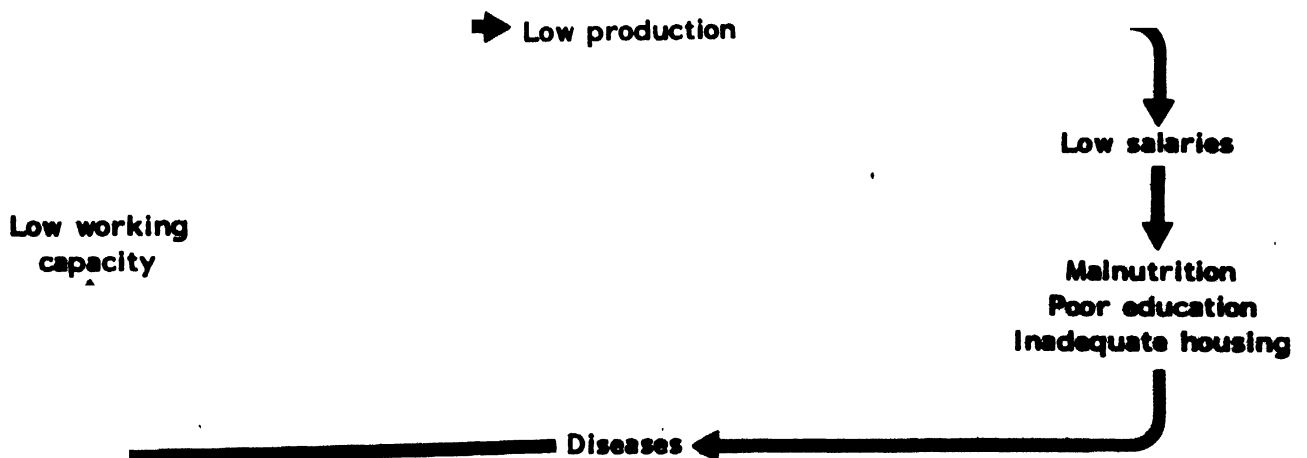


Fig. 1 ECONOMIC CYCLE OF DISEASES

To break up this cycle Strehlke (1979) has suggested several improvements. His main idea is that governments and employers should improve the working and living conditions of forest workers in line with economic progress. Favourable working and living conditions are necessary to reach a satisfactory level of productivity. However, excessive social cost may deprive the industry of its viability and can lead to the closing down of uneconomic operations or enterprises. Governments, employers and workers must therefore strive to reach a balanced consensus on this issue.

Some basic measures which have to be taken into consideration when discussing working and living conditions are the following:

- Basic medical care for workers and their families is indispensable under tropical conditions. This should be the concern of either the community or the employer;
- Hard forestry work is attractive only if the pay is adequate. Low pay will attract some floating labour but regular and fair salaries will increase workers' job-satisfaction. A regular and reliable workforce is a prerequisite for a healthy company. Earnings should be increased through piecework or bonus systems which at the same time might serve as incentives for greater working productivity, better machine maintenance, etc. Trained workers should get higher wages than untrained ones in recognition of the higher quality of work and less supervision;
- The key personnel (tree fellers, machine operators, maintenance personnel and supervisors) should always get vocational training. Untrained workers are expensive for the company, causing excessive wood losses, accidents and equipment down-time;
- Employment should be provided on a regular basis. A stable workforce is a more efficient one, ensuring the recovery of investments in training;
- Basic commodities such as food and fuel should preferably be supplied from local resources. Families should have at least a garden of reasonable size on good land with adequate water supply in the vicinity of their home. Furthermore, the participation of local people in agroforestry schemes may be helpful;
- Sound labour-management relations are another requirement for good working conditions.

5. SAFETY MANAGEMENT

In addition to the forestry environment and the labour force the management aspect must be taken into consideration. The management is naturally most interested in keeping the company continuously in business, so production has to attain an acceptable level, the cost structure must be sound and the quality of products acceptable to the customers.

As mentioned in Section 2.1, the productivity of well-trained forest workers was in one case 25 percent higher than that of untrained workers. The accident rate for young and untrained workers is much higher than for trained men; and accidents cause loss of production, uncertainty among the workers, absenteeism, etc. From the management point of view good production is often the result of proper training and sound labour-management relations.

Lack of vocational training and poor labour-management relations often become apparent in expensive costs for occupational accidents and illnesses. According to Conway (1976) the ratio of direct cost of accidents (lost wages, compensation, medical expenses) to indirect cost (production loss, equipment and material damage) is variously set in the USA at 1:4 or 1:2. In the author's experience the situation is totally different in developing countries where wages are low and often no compensation is paid. On the other hand the machines are very expensive and sometimes difficult to get. Some examples show that the ratio is often 1:10 or even more; for example, the loss of US\$100 in wages and medical expenses is only a fraction of the loss caused by an overturned truck (US\$10,000 in repairs and lost production without including the so-called shadow costs of imported spares).

There is a direct correlation between vocational training, safety, efficient production and production costs. The quality of the product depends heavily on the training of the labour force, and a well-trained, well-nourished and satisfied workforce is well-motivated to do its work.

6. ACCIDENT- AND ILLNESS-PREVENTION PROGRAMMES

6.1 Objective

The alarming accident and health situation in forestry work in developing countries must be improved through better training of management and workers by applying ergonomics in forestry work.

6.2 Accident and health statistics

Accident prevention in developing countries is today largely based on statistical data and research findings from industrialized countries. Corresponding information from developing countries is needed in order to draw up accident-prevention measures in line with local needs and requirements. Especially important are data on the frequency, severity, and direct and indirect costs of accidents. In addition, information is needed on the reasons for absenteeism. Knowledge of these may influence decisions on the technology chosen in developing countries because the side effects and hidden costs of different technological alternatives will be seen more clearly.

6.3 Strong management commitment

There is a direct correlation between good management and a good safety record. Management alone is responsible for employee training and for providing a working environment conducive to the safety and physical and mental fitness of employees. Management is also responsible for control and minimization of physical and mechanical hazards and the prevention of unsafe actions on the part of employees. In logging, as in any other business, the chief reason for a poor safety record is poor management and lack of adequate supervision.

Responsibility for safety and accident prevention must rest primarily with the supervisor who is in direct charge of the operation. He must have the manager's support. The key person to help the supervisor achieve a good safety record is the foreman.

6.4 Participation and personalization

Personal job-satisfaction comes through participation. His work becomes more important to the employee who has taken part in developing it at safety meetings and on the job. If an accident- and illness-prevention programme is personalized the climate is good for active cooperation between the management and the workers; and it is stressed that participation and personalization are as important in developing countries as in industrialized ones.

6.5 Adequate nutrition and the workload

It is evident that the level of nutrition plays a profound role in work output, also that the lack of food contributes to lower resistance to disease and leads to higher absenteeism and a higher rate of accidents. A forest worker's nutrition should be adequate in calories for his heavy workload. Loggers especially need a lot of food. Their daily energy need may be about 4,800 kcal (20,000 kJ), compared with drivers who need only half the amount. This extra need is borne in mind by a good management.

The nourishment of workers during the working day is a problem to be solved. Under tropical conditions the employer has to take care of this issue, providing an adequate lunch (such as light porridge with sugar) and enough water. This is a prerequisite for efficient work without fatigue and strain and will reduce the number of accidents which happen when workers are exhausted and no longer alert.

Forestry work, especially logging, is heavy work often performed in difficult environmental conditions (rain, heat, etc.). It is attractive only if the pay is adequate and in relation to the workload. The pay system has to be planned accordingly. Perhaps the most suitable types in remote areas and forestry conditions are bonus and piece-rate systems. Both will allow the worker to develop his skills and earn more money. The system has to be developed in such a way, however, that the logger's workload remains at a moderate level, taking into consideration possible environmental effects (heat, etc.) on the work. (See Heat stress in forest work, FAO, Rome 1984.)

6.6 Protective equipment and correct tools

Protective equipment will depend on the work to be done and the tools used. If only hand tools are used in logging, helmets and boots are the most necessary protective equipment. It is a different matter where logging with a chainsaw is concerned, because in this case in addition to loggers' personal protective equipment (hearing protectors, wire-mesh visors, safety boots, gloves, overalls, helmets) the saws have to be equipped with chain brakes and anti-vibration handles and must operate at an acceptable noise level.

It goes without saying that the above equipment is common in most industrialized countries. In developing countries, however, most of these items are simply not available and have to be imported, but because of limited foreign-exchange allocations they may not be given high priority by the government. The company management has therefore to decide on the level of mechanization to be used, taking into consideration the effects on workers' safety and health if protective equipment is not available.

Using suitable tools is a way to reduce strain and increase efficiency. Where hand tools are concerned there are some basic principles:

- the tool must be efficient and safe;
- its size and measurements must be in correct relation to the anthropometric measurements of the worker;
- the worker must be able to work in a natural position;
- the tool must cause the worker as little strain as practicable (for example, an axe should have the correct weight and balance).

The cost of buying well-designed and safe tools and equipment is quite reasonable compared with that of machinery. The following relative cost figures may give some idea of the scale:

- The delivery price of all tools and equipment for a well-equipped felling and skidding crew (16 people) using hand tools (crosscut saws, axes, hand-sulkies and the necessary protective equipment (helmets, boots) = 100;
- Delivery price of a well-equipped agricultural tractor (medium size) with winch = 600-700;
- Delivery price of a sophisticated forest tractor, skidder or forwarder = 2 000-3 000.

6.7 Instruction and supervision

Apart from workers' training being limited in many countries to brief on-the-spot instruction (see Section 2.1), training and supervision are problematical because forestry and logging are area-intensive, and the worksites are far apart. If the logger has to use new tools different from those he has used before, the situation is even more difficult. Often he will revert to more primitive, more traditional tools with which he feels more familiar.

Therefore an essential part of accident- and illness-prevention programmes is well-planned training of personnel at all levels. Workers' training may be implemented in many ways. The commonest is to provide on-the-job training in which the foreman introduces the newcomer to the work and later puts him to work with an experienced worker. A more advanced method is to arrange, for example, a two weeks' introductory course for newcomers followed by on-the-job training. The most advanced methods are to give regular vocational training in long, specially-planned courses or basic forestry education at vocational level.

7. CONCLUSIONS

"A healthy and satisfied worker is a productive worker" (Harstela, 1983). This is the basis for sound management-labour relations. The companies with the best safety records are well-managed, with skilled, efficient supervision and well-trained employees. They are also the companies earning the highest net profits (Conway, 1976). Although this observation originated in an industrialized country, the economic aspect applies also in developing countries.

BIBLIOGRAPHY

Axelson, O. Heat stress in forest work. FAO, Rome.
1974

Conway, S. Logging practices. USA.
1976

Forestry Training Programme (FTP) Seminar on logging ergonomics,
1983 Dehra Dun, India. Working papers:
- Bostrand, L. Ergonomics in forestry training in Asia.
- Harstela, P. Introduction to ergonomics.
- Harstela, P. Ergonomics applied to forestry.
- Strehlke, B. Safety in logging.
- Strehlke, B. Working and living conditions of logging
workers.

Frykman, B. Aspects of ergonomics and safety to be considered in choice of
1982 technology. FAO Forestry Paper No. 31, Rome.

ILO Choice of technology in forestry: a Philippine case study.
1981

Strehlke, B. Vocational training in forestry. FAO publications.
1979 Logging operations: report of the FAO/Norway training course.

**MAINTENANCE AND REPAIR MANAGEMENT OF WOOD HARVESTING TOOLS,
EQUIPMENT AND MACHINERY**

by

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1. INTRODUCTION

The reliability, durability and productivity of any tool, equipment or machine depends on its correct maintenance and repair. In industrialized countries a reliable, speedy maintenance and repair organization is a prerequisite for the sale of any equipment or machine. The costs of maintenance and repair in these countries are sometimes so high compared with the price of a similar new item, however, that an increasing number of users has found it more economic to change to the use of disposable tools, equipment and even machines. The main reason for this situation is the high labour cost compared with relatively low manufacturing costs. Large-scale manufacturing costs can be kept low because of highly sophisticated, capital-intensive production methods.

In developing countries the situation is quite different: labour costs are very low compared with capital costs. Correct maintenance and repair are therefore particularly relevant. In many cases it is even profitable to repair and utilize discarded tools, equipment or machinery instead of throwing them away as useless. Thus maintenance and repair are an essential part of the planning and implementation of wood harvesting operations in developing countries.



Locally-made neck-yokes
(Border Timbers Ltd.) (Photo: H. Seppänen)

This paper attempts to outline an advance from the simplest tools and equipment to appropriate or intermediate technology, with cost-effectiveness always in mind.

2. MAINTENANCE AND REPAIR MANAGEMENT IN RELATION TO THE LEVEL OF MECHANIZATION

Decades ago, forest harvesting operations in most industrialized countries were carried out by labourers who supplied their own basic tools and equipment. They themselves maintained their axes, bow saws and crosscut saws. The transport of timber to the side of the truck-road (0.1-10 km) was normally carried out using animals, in most cases horses. The horses, sledges and carts were owned by private farmers who maintained their property themselves in order to use their resources most efficiently and profitably.

At that time no special maintenance organization was needed. The local blacksmith was an essential link in an unofficial system; he made the necessary repairs and could even manufacture axes and equipment for sledges, etc. Some tools, mainly sawblades and axes, had to be bought.

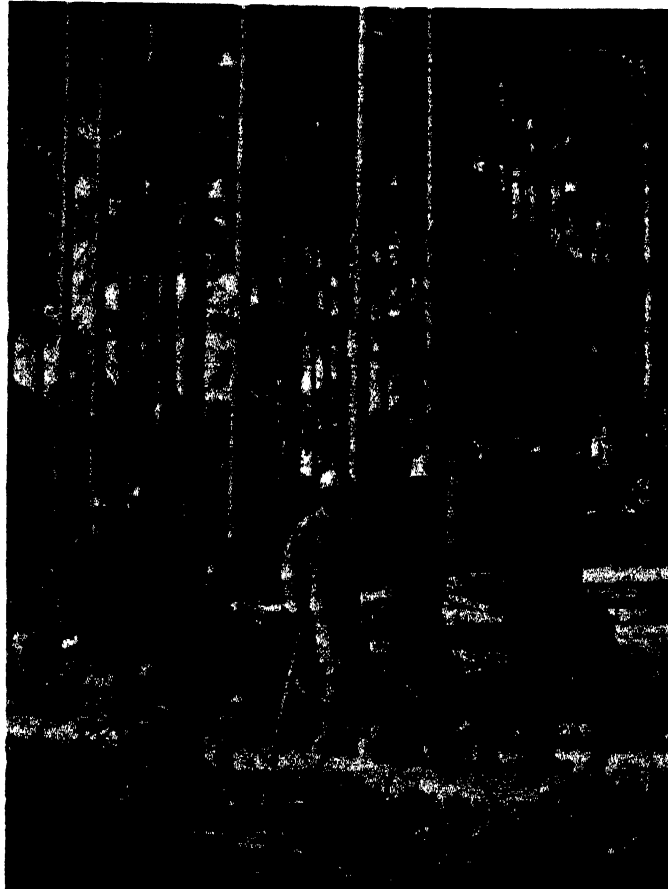
Later on, when chainsaws and agricultural tractors were introduced, the need for more extensive maintenance and repair became urgent. Even then it was private operators who took the initiative in using the new inventions, mainly because they quickly realized that the economic benefits were greater. The first experiments were often disastrous for individuals; the cost of inexperience can be high indeed. Some of the failures and disasters could be blamed on insufficient basic training, poor availability of spare parts and nonexistent or weak maintenance organization. To avoid expensive downtimes (times when machines are idle) a transport network needs to be of a sufficiently high standard. In the early days of mechanization this was not the case.

It soon became evident to the manufacturers of tools, equipment and machines that they would not be able to improve the sale of their goods unless the shortcomings mentioned above were put right. Labour costs went up greatly in the nineteen sixties and seventies compared with the cost of machines. Nowadays the time which is spent "uselessly" in waiting for an essential spare part is generally short, even in relation to the original price of the machine. This state of affairs has been achieved because of the large numbers of machines and efficient service organizations.

The most expensive, sophisticated, multipurpose harvesting machines cannot be kept waiting for spare parts or the arrival of a mechanic for several days, in extreme cases not even for some hours. The manufacturer and/or dealer has to make available a service organization which can at any time and at short notice be sent to carry out quick and efficient maintenance and repair work and so avoid expensive downtime.

In industrialized countries normal maintenance and repair of forest machines are carried out in the forest. Occasionally annual service and major repairs only are done at a central workshop. In developing countries the situation is fundamentally different. Unfortunately this is something that many donor countries have not yet realized. These donors have been eager to introduce new, advanced working methods and machinery without first ascertaining the real capacities of the recipient countries to maintain and repair the donated machines well enough to ensure that they will function as they should for a reasonable time. Often this usable machine time, that is, the expected lifetime of a machine, is in developing countries only a fraction - perhaps one-third or even less - of the lifetime the same machines have in

industrialized countries. From this it can be inferred that the running costs will grow considerably and the entire cost structure of the enterprise will change. These economic realities tend to be underestimated in development cooperation and various aid projects.



A final cut crew consisting of a chainsaw operator and five men. The daily production, felling, bucking and debarking, in a nine-year eucalyptus (Eucalyptus cloezavira) stand was about 120 trees (Wattle Co. Ltd.) (Photo. H. Seppänen)

3. MAINTENANCE AND REPAIR MANAGEMENT OF BASIC HAND TOOLS

In the developing countries of Africa the tools, equipment and machines needed in wood harvesting are normally the property of the employer. They are also with few exceptions imported, and their replacement is largely dependent on the availability of foreign exchange. In building a maintenance and repair organization these issues must be taken into consideration as well as some other facts:

- the general background (social and cultural) of the workers;
- daily transport of the labour, tools and equipment to the forest and back, and reliability of the transport;
- permanent or casual labour to be used;
- the general level of management.

3.1 Appropriate hand tools

3.1.1 Ownership of the tools and equipment

The most commonly used hand tools in tropical forestry are matchets, axes and saws (bow saws and different crosscut saws) for felling and hoes for road building and maintenance.

A fact often joked about but nevertheless undeniable is that tools owned by the employer will wear out faster than those owned by the worker himself. In developing countries the tools, being usually owned by the employer, may on occasion be more carelessly used and maintained than would be desirable. In an organization where the labour force is permanent and stable some system of leasing tools to the employees could be tried as an experiment. Experiences in industrialized countries favour this system which in fact is the normal way to change over to more advanced ownership of tools and machines. Good care of tools will be rewarded by better income, and longer life-expectancy for the tools.

In most developing countries initial purchase of the tools has to be by the employer because at the moment proper tools for logging are either difficult or impossible to obtain locally. In the long run appropriate hand tools like axes should be manufactured in each country to avoid spending foreign currency on them. And every country which grows timber should certainly be capable of producing its own axe handles from some local timber.

3.1.2 Maintenance and repair organization

In all maintenance the basic principle is that the logger himself should do as much of it as he can. Centralized maintenance organizations should be kept at a minimum so that there will be no unnecessary transport of tools to and from the workshop. This is not only to save time; the logger will also take greater care of his equipment and keep it in good condition when he knows that his earnings depend on it.

Axes and also wedges, hoes and spades can in most cases be maintained by the worker himself. For this purpose he does not need more complicated equipment than a whetstone and a file. For a periodic, more thorough maintenance like a monthly service, there are two alternatives. It can be carried out in the central workshop using grindstones located there. Grindstones are so easy to use, however, that in most cases it is more appropriate to train the worker to do the monthly maintenance of his tools himself. Grindstones can also in most cases be produced locally.

Maintaining saws can sometimes be more complicated. It is difficult to file a bow saw and not every logger can be trained to do this himself. For this operation a featheredge file is required, and appropriate training. Peg-toothed crosscut saws are still more difficult and their work performance depends largely on the sharpness and the setting of the saw. It is possible to learn in a day or two how to keep such a saw in good working condition. In an advanced logging organization with permanent labour this work might be left to experienced, trained workers who in this way would get more responsibility and also earn bigger salaries, to stimulate their work motivation and further development.

Most difficult to maintain and keep in good working condition are rake-tooth crosscut saws. These are the most efficient when properly kept. Their maintenance requires special setting and sharpening tools which it is not

normally practical to give to the workers. To train a worker well enough takes at least two weeks and after that a longer period of practical on-the-job training. Rake-tooth crosscut saws should usually be maintained every week, but if the saw is carefully kept the interval might be stretched to two.

The general tool maintenance of a harvesting unit depends largely on the size of the operation. If the work is carried out solely with manual tools, a worker's output varies from about 1.5 m³ per man/day in thinning to about 2.5 - 3.5 m³ per man/day in clearfellings. This means that a small mill consuming 2,000 m³ a year needs 5-8 loggers assuming that the number of annual working days is about 180-200.

For operations of this size only one part-time maintenance worker is needed, who would have time enough to repair sulkies and assist in other duties as well.

If the mill has an input of 10,000 m³ - which is quite large for African conditions - the logging labour force necessary is 30-40 people if they use only manual tools. In this case the workshop needs on average two mechanics who are able to carry out regular periodic maintenance. If the logging units are relatively far from each other, it is preferable to have two separate small workshops to avoid unnecessary transport which is often a problem in developing countries. It is essential that the services of the mechanics are used, because the loggers' output depends largely on good tool maintenance. The mechanics should be rewarded when the logging output increases or the work is otherwise praiseworthy.

Astonishingly, axe handles are not commonly manufactured locally, and sometimes they are even imported into developing countries from overseas. As already mentioned, axe handles are one of those items which can and should be produced locally in any country practising forestry. Some basic training and guidance are necessary, but after that every worker should be capable of making his own handles for axes, spades and hoes.

It is important in the economic conditions prevailing in Africa that industrial enterprises should concentrate on such tools which can be manufactured locally. In Finland, for instance, even bow-saw frames were made by the workers themselves up to the nineteen fifties. When there is a real need, people start to use their own initiative, especially if there is a reward for their effort, for instance in the form of raised income.

Note: More information about the manufacture, care and maintenance of hand tools can be obtained from books such as "Selection and maintenance of logging hand tools", ILO, Geneva 1970, and "Field handbook, choice of appropriate technology in Philippine forestry", ILO, Manila 1982.

3.2 Chainsaws

Chainsaws are always imported into developing countries. They need a regular supply of spare parts and they consume a lot of imported fuel and lubricants. For completely untrained and also inadequately trained workers they are very dangerous to use. In most cases their profitability cannot be proved. And yet, in spite of all these negative aspects, trees in many forestry enterprises in developing countries are felled only with chainsaws.

3.2.1 The ownership of chainsaws

In some industrialized countries chainsaws are owned by individual workers, in others by the employer. If the worker owns the saw himself he will also see to its maintenance and repair. Major repairs are often done at the workshop of the local dealer, but in this case too, the worker will take care of the entire matter, including taking the saw to and from the workshop. The cost of maintenance and repair is usually covered in the unit price of chainsaw work.

In developing countries chainsaws are almost always owned by the employers and because of the economic situation it seems unlikely that this will change in the near future.

3.2.2 Purchase of chainsaws and supply of spare parts

In industrialized countries the price of a chainsaw is equivalent to one or two weeks' salary of a worker. They are therefore relatively inexpensive by comparison with their relative cost in developing countries where the price might be equivalent to anything from half a year's to one year's salary. If all the additional costs are included, the real price of a chainsaw might vary from one year's to several years' earnings. So it is understandable that a worker cannot buy a chainsaw to use at work.

It follows that the introduction, maintenance and use of chainsaws has to be carefully planned, and special attention must be given to the spare-part supply. It is irresponsible and shortsighted to introduce models for which a spare-part supply has not been organized in the country. A vague promise of such an organization "in the near future" has no value, as the near future is without exception too late. It is unfair to a developing country to import a model, the spare-part supply of which is entirely dependent on the availability of funds from some donor country or aid agencies. This has happened in many developing countries; and if the donor country for some reason or other does not continue to fund the purchase of spare parts, the saws are stored or simply abandoned.

If it is judged wise and necessary to introduce chainsaws into an enterprise, it is prudent to choose the model which is most used in the country.

When chainsaws are ordered, enough spare parts should also be ordered to keep them profitably running for a reasonable time. In some projects the rule of thumb is to make this period two years.

All too often only a few spares of a certain kind are ordered initially with the saws. The result of this shortsighted practice is that some of the saws must finally be stripped and cannibalized to enable at least a few to be used.

Spares are not the only equipment necessary for the proper maintenance of chainsaws. Quite often the timely ordering of such necessities as files is forgotten, and yet it should be evident that chainsaws cannot be operated for long without the right type of files to maintain the chain.

3.2.3 Maintenance and repair organization for enterprises using chainsaws

3.2.3.1 Industrialized countries

As with hand tools the basis for chainsaw maintenance is that the worker himself should be trained to do as much as he can. Because a chainsaw is more

complicated than hand tools, the amount he himself can do depends largely on both his educational level and the level of the training he has received. This can on occasion cause problems, but there are industrialized countries where the worker carries out most maintenance and repair (usually when he owns the saw). In such cases the price of the saw has to be rather low compared with the earning level of the worker.

Other solutions and systems are also used in industrialized countries. If the chainsaws are owned by the enterprise and the logging area is extensive (with a radius of about 100 km), the chainsaw maintenance organization may be as follows:

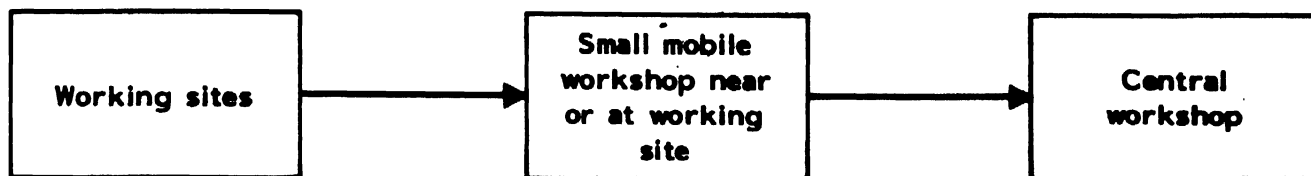


Fig. 1 CHAINSAW MAINTENANCE ORGANIZATION WITH MOBILE WORKSHOP

In this system the loggers have extra chainsaws with them at the work site and should the need for some maintenance or repair arise (excluding normal sharpening of the chain teeth) the logger will set aside the saw needing maintenance and use another. The first one is taken during lunchtime or at the end of the working day to the mobile workshop. Usually maintenance or repair is carried out there, and only if the mechanic cannot repair the saw in the field will it be delivered to the central workshop.

3.2.3.2 Developing countries

The productivity of a well-trained worker using a chainsaw is very high compared with that of one doing the same work using only hand tools (though this does not mean that the unit costs are lower). If chainsaws are used only for felling and crosscutting, as is normally the case in developing countries, productivity is somewhere between 10 and 20 m³ per man/day, depending to some extent on the size of the trees, the density of the stand, the heat, etc. For a mill consuming 2,000 m³ a year only one operator and one helper would be needed to fell and crosscut the trees, with others to delimb and pile. It should be noted, however, that delimbing and piling require about 50 to 70 percent of the total working time depending on the tree species; and there must be extra chainsaw operators to ensure the smooth running of the operations in case of illness, accidents, etc.

Normally it is the responsibility of the logging manager to keep the mill properly and adequately supplied. His main concerns are therefore the bottleneck areas of log supply. In developing countries these bottlenecks are usually caused by the machines (trucks, tractors, chainsaws). The maintenance of hand tools needed in logging is normally separated from the main mill workshop, because the spare-part store and the small chainsaw workshop naturally form an integrated entity that can usually be made the responsibility of a trained and specialized chainsaw mechanic. It is his duty to ensure that spare-part requisitions are prepared and forwarded in time and that the saws are always in good working condition. It is his duty too to report if and when the saws are not well maintained and handled.

The maintenance of chainsaws and hand tools is often organized in the following way in an enterprise where the annual logging volume is 10,000 m³ or more:

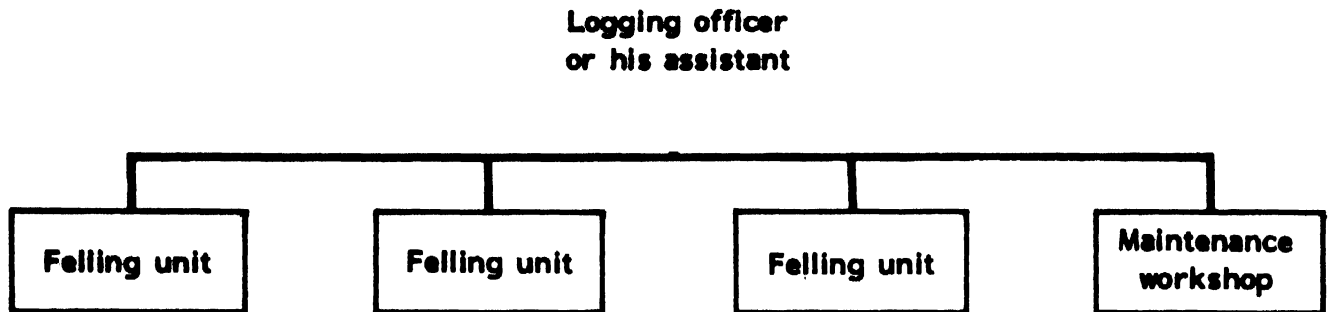


Fig. 2 MAINTENANCE ORGANIZATION FOR AN ENTERPRISE LOGGING 10,000 M³

3.2.4 Maintenance schedules for chainsaws

In industrialized countries the lifespan of a chainsaw is normally about one year or 1,200 - 1,500 machine hours of hard work. In developing countries it often happens that a chainsaw in hard work lasts only a couple of months or less than 500 hours. The machine costs of using a chainsaw are therefore much higher in developing countries - if labour costs are not included. This state of affairs is further worsened by the unavoidable import of inputs. To make the use of chainsaws more economic there are two essential issues which should always be taken into consideration and put into practice:

- proper training of chainsaw operators and mechanics;
- regular maintenance.

Note: For this paper only the various items in daily and monthly maintenance are mentioned. More information can be obtained from the booklet "Chainsaws in tropical forest", FAO, Rome 1980.

3.2.4.1 Daily maintenance

Daily maintenance is the duty of the chainsaw operator for the simple reason that any other solution would be highly impractical. The following details should be checked and the necessary adjustments made once or possibly several times a day:

- sharpening the chain teeth (always after filling the tank)
- cleaning the air filter
- checking that oil is flowing to the chain
- checking that the chain has the right tension
- checking and tightening nuts and bolts
- checking the chain brake
- cleaning sawdust from the saw after work.

3.2.4.2 Periodic maintenance (1-2 times monthly)

The periods between the bigger regular maintenance operations depend largely on the worker's skill in handling the saw and the daily use, thus no exact time can be given. The following tasks should be carried out regularly:

- cleaning the fuel system filters
- checking the chain sprocket
- checking and adjusting the sparkplugs
- checking and lubricating the clutch bearing
- cleaning the exhaust channel and silencer
- cleaning and lubricating the starter spring
- turning the guide bar.

3.2.5 Training of chainsaw operators and mechanics

In industrialized countries the special training of chainsaw operators usually takes more than a year, that of mechanics even longer: about three years. Its main aim is to try to ensure smooth and effective working with a minimum of hazards.

The situation in developing countries is different. In many forestry enterprises the chainsaw mechanic may at best have had a couple of weeks' training on the job, while chainsaw operators have had no formal training at all and their only recommendation for the work is frequently some earlier practical experience. Their working methods are therefore not necessarily the best from the point of view of productivity, work safety or economic running of the machines.

From the maintenance and repair management point of view there are two ways of reducing the costs of using a machine:

- training the operator to use it correctly;
- training for better maintenance and repair.

It is evident that in the near future the developing countries cannot achieve or maintain a heavy and demanding training system like that in industrialized countries. Lighter training will have to suffice - but considering the price of a chainsaw and its spare parts it is clear that there must be more training than at present. The price of labour being low compared with that of the saw, it is more useful to train the worker properly than to put him straight to work and shorten the lifespan of his equipment. Proper training is the best guarantee of good maintenance and a reduced number of breakdowns.

3.2.5.1 Operators

The Forestry Training Programme (FTP) has annually conducted several chainsaw handling and maintenance courses in different developing countries. Experience from this training has shown that the minimum length of a course for chainsaw operators is one month. It is advisable for participants to have some months' working experience as helper to a chainsaw operator before the course. After completion of the course 80-90 percent of the trainees have expressed the opinion that they would need two more weeks of training.

From frequent bitter experience it can be stated that only properly trained operators should be allowed to handle the chainsaws. The less experience and training, the greater the risk of accidents, even fatal ones. It is the head of

the logging organization who is taking unfair and unnecessary risks if he employs untrained workers for chainsaw operation. If proper training is for some reason or other not possible, the work should be carried out using appropriate hand tools (bow saws, crosscut saws and axes). The possibility of dangerous accidents is then much smaller.

Logging enterprises should always maintain close cooperation with training institutions so that they can obtain the course content material (if they themselves are capable of organizing training) or even discuss the possibility of specially tailored courses, for instance, if chainsaws are only just being introduced.

3.2.5.2 Mechanics

Not everyone can be trained in mechanical skills, so it is sensible to select trainee chainsaw mechanics from among workers who have already had vocational training as mechanics. A good level of maintenance cannot be maintained without a thorough understanding of machines and their accessories; simple on-the-job training is not enough to make a good mechanic of a worker without basic training. In addition, the trainee should work at least some weeks in normal logging tasks so that he can gain insight into the real conditions in which the saws are operated. It will then be easier for him to understand how faults are most likely to develop - knowledge which can greatly help him in his work.

After completing his training a new chainsaw mechanic cannot be considered competent to begin to work on his own. He still needs the guidance and supervision of an experienced mechanic for many months before he can take the responsibility for an entire workshop on his shoulders. In addition to the normal tasks of maintenance and repair he must learn how and when to order spare parts, and what quantity should always be kept in store. He also needs some skills in bookkeeping for the store.

It should be noted that car mechanics do not automatically qualify as chainsaw mechanics, for the two types of engines are basically too different.

4. MAINTENANCE AND REPAIR MANAGEMENT OF TRACTORS AND TRUCKS

Tractors and trucks are usually the chief cause of concern, and headaches, for logging managers in developing countries because they represent the main logging cost. In modern systems tractors and trucks are indispensable because without them it is almost impossible to deliver logs to the mills.

If an enterprise uses contractors for transport, bottlenecks can often be avoided because it becomes the duty of the contractor to take care of these necessities against a certain charge. Many private mills use contractors as a part of their transport arrangements. This is often a rational and profitable approach because the use of several channels rather than only one will better ensure the constant flow of raw material to the mills.

One of the reasons why contractors are not always used in developing countries is the development cooperation procedures whereby new machines are delivered from industrialized countries to parastatal enterprises or governmental organizations on an aid basis. It has been noticed in many developing countries that a contractor seems to have more chance of successfully tackling the difficult matter of spare-part supply than the more bureaucratic parastatal organizations.

In this paper agricultural tractors are discussed in more detail than highly specialized, more sophisticated tractors and trucks. Generally it can be said that maintenance and repair management of the latter is similar to that of agricultural tractors, the differences being that they need more trained maintenance personnel, both in number and skills; a better developed spare-part supply with an easy quick access to foreign currency (needed for air transport of spare parts, for instance); and better-equipped workshops.

4.1 Agricultural tractors

With the money needed today to purchase even the cheapest tractor it would be possible to buy 30-40 chainsaws. This huge investment for tractors makes it all the more important that they should be handled with due care and expertise.

4.1.1 Ownership of agricultural tractors

In industrialized countries it is quite common for people to possess agricultural tractors solely for their own private use and in some cases also for contract work. In developing countries very few people can afford a tractor of their own. Therefore this paper will discuss company-owned tractors only.

4.1.2 Purchase of agricultural tractors and their spare-part supply

As in the case of chainsaws, the basic principles in buying the machines and securing a supply of spare parts are:

- to avoid expensive and time-consuming bottlenecks in repair operations and spare-part supply and to ensure that the model chosen is commonly used in the country;
- at the time of purchase to order enough spares to last for a certain period, usually at least two years, because it is always possible that spares for that particular machine might not be obtainable in a hurry.

There are additional requirements in the case of agricultural tractors:

- There must be a well-maintained central workshop network for the particular model in the country, from where the more expensive spare parts can be obtained without delay;
- Adequate introductory training for mechanics and operators must be organized and carried out by the local dealer. If this cannot be arranged, the purchase should be reconsidered and other alternatives sought;
- The tractor should be simple and durable without unnecessary sophisticated or complicated accessories which are difficult or impossible to repair in that country. The following accessories, for instance, should as far as possible be avoided when tractors are chosen for hard forest work: power steering, automatic transmission, turbo charging, difficult hydraulic systems. These will only cause trouble when they break down, and the work does not normally require them;

- A tractor should be selected together with its accessories, trailers, etc. and attention must be paid to ensuring that they all form a good and efficient combination. Often a powerful tractor is seen pulling a tiny trailer, which is a waste of energy. On the other hand, because of the lack of proper control trailers are often overloaded in developing countries;
- There must be a reasonable prospect of securing enough fuel and lubricants for the machine; and there should be a contingency plan for obtaining them in the inevitable times of scarcity;
- Good operators and mechanics must be available, and must be offered competitive salaries. Fringe benefits including housing must be planned in advance;
- The supply, maintenance and repair of tyres must be arranged;
- There must be a properly equipped workshop.

If all these details have been carefully planned and the costs estimated, and the final calculations - with shadow prices included - show that the unit costs for doing the intended work with a tractor are lower than with manual and/or animal power, then, and only then, is it advisable to go ahead with ordering the tractor.

Here it may be useful to include the reminder that money is the best adviser when the purchase of a machine for a developing country is being considered. Because it is sometimes difficult to decide which rates should be used when machine purchasing and running costs are calculated, it is advisable to make estimates using both official and unofficial rates. A shadow price study should also always be made if a development cooperation agency is involved, otherwise it is difficult to judge whether the investment is viable or not.

4.1.3 Maintenance and repair organization for enterprises using agricultural tractors

In industrialized countries the owner of the machine and/or its driver are usually able to do the regular maintenance and repair work themselves, and only the major service is done by a qualified mechanic. In a developing country this is not normally the case. The driver is often capable only of operating the vehicle; his knowledge of the engine and its maintenance is all too often almost nonexistent because his training has been solely in driving. Similarly, the mechanic has often been trained for maintenance and repair work only; he is not used to operating the machine, and in some instances has not even been allowed to try it. In these conditions cooperation may be difficult and a clear administrative and organizational system is necessary to manage the work.

In small enterprises all the maintenance and repair work for the mill and the logging and transport fleet is carried out in the same workshop. In bigger enterprises there are separate workshops for different sections. The following example shows the organization of a logging and roadbuilding machinery workshop maintaining a fleet of 10 tractors, 8 trucks (2 for roadbuilding and 6 for logging), 2 bulldozers, 2 graders, a low-loader, an excavator and 5 vehicles:

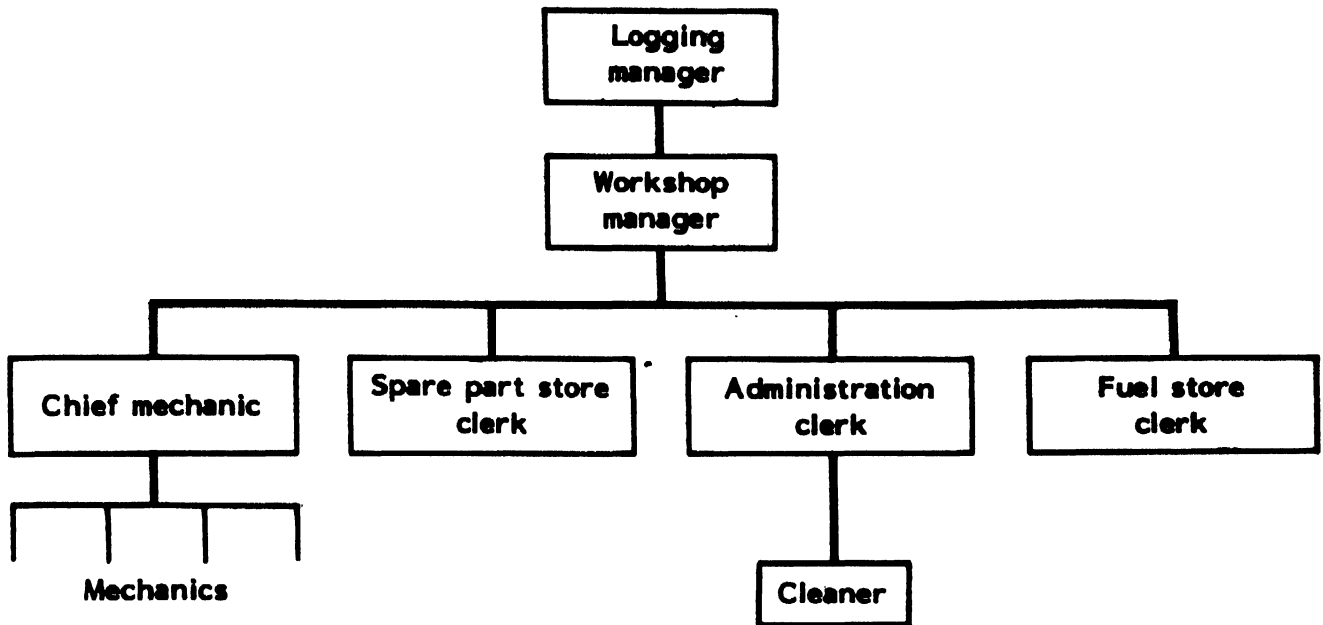


Fig. 3 STAFF ORGANIZATION IN A MAINTENANCE WORKSHOP

The workshop manager is in charge of the maintenance and repair work of the entire logging and roadbuilding fleet. He works directly under the supervision of the logging manager.

The chief mechanic works in close cooperation with the workshop manager and acts as his deputy. The clerk dealing with the spare-part store has total responsibility for the spares and it is his duty to give continuous information on their availability to the workshop manager. He also maintains a spare-part card index. To ensure order in the store no-one should be allowed to enter without his permission.

The administration clerk takes care of the maintenance books for tractors and other machinery. Each machine has an individual book and all the services and repairs on that particular machine must be carefully listed in it. Each spare part and the working time needed by the mechanic are recorded. The cost of the work including the mechanic's salary is calculated daily. These particulars are then carried over to the daily and monthly record books of the workshop and so reported to the administration.

The fuel store clerk is in charge of fuel and lubricant supplies and the relevant bookkeeping. He informs the workshop manager when the stock has diminished to below a certain level and must be replenished. He also calculates the monthly fuel consumption of the machine.

The mechanics working under the supervision of the chief mechanic are specialized in certain machines. It is often sensible to have them take care of the same type of machines, so that their understanding and experience of those machines is increased and they can get them repaired faster. Specialized mechanics are particularly needed to maintain heavy machines because they are often complicated.

In this type of organization the machine operators should participate in the maintenance and repair processes and help the mechanics as much as they can. They must also inform the workshop about any abnormalities in their machines, such as too-heavy consumption of fuel, or noise.

Maintenance organizations naturally vary a lot depending on the size and type of the enterprise. Whatever the variations, the organization structure and the sequence of authority must be clear. Each worker should know what his duties and responsibilities are and every completed job must be submitted for inspection by the workshop manager or his deputy before the machine is allowed to leave the workshop. In this way the roadworthiness of the machine is not determined by the mechanic alone.

4.1.4 Working times

It is more or less the prevailing practice in industrialized countries to use machines in two or even three shifts, because in this way it is usually possible to reduce costs. In developing countries, if machines are used the greater part of logging costs is machine costs (depreciation, interest, fuel, tyres, maintenance and repair, spare parts) and so it is extremely important to use the machines efficiently. This quickly leads to the same practice found in industrialized countries: machines are often used, especially by private contractors, for longer shifts or even for two shifts.

In the conditions prevailing in developing countries the two-shift system is not often advisable, because then the care of expensive machinery tends not to be as good as it is when only one driver working one shift is used. In most cases, however, more attention should be paid to the possibility of using machines in longer shifts; for operations using machines are often heavily inflated because of inefficient utilization.

If the machines work for longer shifts, the workshop system has to undergo some changes. The workshop has to be open for the whole shift or, if that is not practicable, at least a mechanic must be available in case something goes wrong. Because of the low labour costs compared with machine costs this should not cause any particular trouble. Efficient use of the (often too small) capital is probably the main worry of the logging manager and the workshop manager has to plan the operation of his unit accordingly.

4.1.5 Maintenance schedules for agricultural tractors

When a new tractor is bought the owner receives with it a service manual giving among other information the manufacturer's recommendations on service schedules. These recommendations should be punctiliously followed, with deviations only to service the machine more often than recommended. For instance, intervals between the changes of oil may be shortened because of extreme conditions (dust, heat, low quality of oil or diesel). It has sometimes happened that because oil or a filter is lacking, changes have not been carried out according to the instructions. This is a dangerous practice which should not in any circumstances be allowed. However big the loss in time and money, use of the machine should be stopped immediately if the scheduled service cannot be carried out. It is less costly to let the machine stand idle than to carry out an extremely expensive overhaul of the engine.

The maintenance schedule of an agricultural tractor should include the following items:

- a daily checkup and the necessary cleaning (e.g., of the air filter in dusty conditions). This is carried out by the tractor operator;
- regular services with intervals depending on the prevailing conditions;
- plus a weekly service (washing, greasing, measuring the air pressure, complete checkup), by the tractor operator and the workshop mechanic together, checked by the supervisor;
- plus periodic services after a certain number of machine hours (for instance, engine oil and filter are always changed after 300 machine hours and transmission and gearbox oil after 600 machine hours).

Appendix 1 A shows an example of a page in a service book for an agricultural tractor. Appendix 1 B provides an easy example of how the monthly and annual service costs of a tractor can be followed.

4.1.6 Training of tractor operators and mechanics

The operational costs of a tractor unit (tractor and trailer or tractor and winch) depend greatly on the skills of the operator and the mechanic responsible for maintenance of the machine. It has already been pointed out that training is an essential part of chainsaw operation and maintenance; how much more so, then, in the case of a tractor and trailer unit which may be 50-100 times the cost of a chainsaw.

In industrialized countries it goes without saying that expensive machines cannot be entrusted to operators who are not properly trained for the work. The same should apply even more in developing countries where the price of the machines is relatively so much higher. Unfortunately it often happens that in a new project the need for operators and mechanics is so urgent that the training aspect is given low priority. Even in projects where foreign sponsors are involved, operators and mechanics will sometimes get only very elementary and cursory training, not nearly enough to carry out the work well and without unnecessary risks.

This state of affairs shows that the project has not been properly planned; and yet it is a position in which newly appointed project managers will all too often find themselves. The work has to be started immediately to reach the targets set by outsiders; the managerial staff might be competent enough, but too little attention has been paid to the competency of foremen, drivers, mechanics and machinists. Recruitment has been quick and often the first breakdowns follow as quickly.

An adequate period of training should be included in the project plan to take place before or directly after arrival of the first consignment of machines; and training should be a continuous process in any development project. There are many possibilities for different training courses, but it may be most advisable for newly established enterprises to make contact with the training institutions and state their needs, so that they can get courses especially designed to meet the company's requirements. If a training institution cannot offer help, the company itself must organize training.

Appendix 2 outlines the objectives and content of a two-week basic course for newly employed tractor operators who have a driving licence but no training in forestry operations. After this course they are allowed to practise for two weeks in the forest, closely supervised by the instructor. Then follows an extension course of two weeks (Appendix 3).

4.1.7 Equipment for agricultural tractor units

4.1.7.1 Equipment for the tractor

An agricultural tractor is not suitable for hard forest work without some adjustment and special equipment. It is easier and often cheaper to have the desired changes made at the factory and to order the necessary equipment when buying the tractor so that it arrives at the work site in the developing country in full working order. The following are necessary before the tractor can be used in forestry:

- safety frame or safety cabin (imperative);
- radiator protection to avoid expensive punctures of radiators;
- tyre valve protection because a small branch can break the valve and tubes are often rare in developing countries;
- front weights to prevent front wheels lifting off the ground;
- front lights either protected or lifted on the bonnet, otherwise they may be damaged by branches or logs;
- tyres 12-ply or more, because frequent punctures delay the work and diminish productivity;
- engine protection on both sides, with steel shields to avoid breakages of air filter, diesel filter, oil filter, oil dipstick, fanbelt, etc., parts of which are outside the engine.

It is not economic to use an agricultural tractor without equipping it appropriately for logging work because recurring breakdowns slow down the work. Nor is it possible to go over to more productive tasks and piecework methods without the right equipment.

4.1.7.2 Special logging equipment

An agricultural tractor working in the forest is usually equipped with a trailer or a winch. Winches are used when the off-road transport distance is short and/or for yarding operations when terrain or weather conditions do not permit surface transport.

There are several makes of tractor-winches whose performance in fact is quite similar. In developing countries it is practical to use double-drum winches with a dozer shield because they are durable and need only simple maintenance and repairs. Also they protect the winch operator. These winches have to be ordered with at least two years' supply of spare parts including enough skidding wire, chains, locks and clutch plates; the lifespan of these items is usually much shorter in developing countries than in industrialized countries.

About the numerous trailer types it may be stated in this context only that the trailer should be chosen so that it is suitable for the size of tractor in

question. It may be advisable to choose a trailer with a smaller loading space than is normally found in industrialized countries because logs in the tropics are often heavier. It is realistic to select a trailer which can be loaded manually in case the loader breaks down. The trailer body should be made for heavy forest work and with a low loading height (to make manual loading easier); it should have releasable stakes for the offloading; and the trailer must have brakes if the terrain is rough and the unit is used in difficult off-road areas. No trailer with payload should ever exceed three times the weight of the tractor.

The question of how to load the trailer is a critical issue in developing countries because of the maintenance and repair problems. Loading by hand is the system least sensitive to breakdown and there are usually many unemployed people who require relatively low pay. Therefore the manual alternative should be considered first. Before plans for tractor-mounted loaders are made, the advantages and disadvantages of both methods should always be calculated.

If mechanical or hydraulic loaders have been used in a working area it may prove psychologically difficult to return to manual loading. If it is decided to buy the machine, it may be wise to buy a mechanical cable loader, as experience has shown it to be difficult to introduce a hydraulic boom loader successfully into a developing country. This can be done only if the enterprise has easy access to external funding and a low cost control, as well as mechanics skilled in hydraulics.

Winches and trailers must be checked and maintained regularly during the scheduled daily, weekly and periodic servicing of the tractors. If a tractor-trailer combination is used for the entire transport from stump to mill, the roadworthiness of the unit must be regularly checked. It is also important from the maintenance and safety point of view to supervise the speed of the unit regularly and to make sure that no passengers travel on top of the logs as this is the major reason for serious accidents.

4.2 Skidders, forwarders, front-end loaders and trucks

The economic situation in most developing countries is rather gloomy and this is one reason why the introduction of sophisticated forestry machines should be very carefully considered.

The wood supply is not often judged by a mill management to be as important as other parts of the forest industry. Often there is an acute shortage of all wood-industry products in developing countries because the number of houses constructed is growing rapidly. The demand for sawn timber and wood-based panels is high and prices are inflated. It is common and easy for a mill management to accept all the raw-material costs as they are because the price of the final product can easily be raised due to the shortage of the commodity. High harvesting and transport costs have therefore often not been reviewed by the mill management in order to reduce them.

It would be advisable in the long run for enterprises to use the economic approach instead of the technological one. In some cases it would be practicable to use only tractors from the stump to the mill instead of the tractor/front-end loader/truck/loader combinations. The timber flow would then be easier to manage, the costs lower and only a fraction of the foreign currency needed compared with the other method. In some cases the economic transport distance of an agricultural tractor can be 20-30 km.

If the logs are big (tropical hardwood), the transport distance long (20 km or more), or the quantity needed large (20,000 m³ or more), then skidders,

bulldozers or trucks might be the only answer. This always requires, however, that the roads are good. If they are not, the trucks, which are designed for road use, have to be replaced by tractors.

When an enterprise is using heavy machinery it happens all too often that the mill is operating at only 20-50 percent of its capacity because there is an insufficient supply of raw material, the machines have maintenance problems, or fuel, lubricants or spare parts are unobtainable. The usual approach to this problem has been to double the amount of logging and transport machinery necessary for the operation; this is highly uneconomic compared with the solution of using better work-orientated methods.

If a company has decided to use these expensive and more sophisticated machines it requires the following:

- a high standard of mill management (cost and production control);
- easy access to foreign currency for machines and spare parts;
- well-equipped workshops with highly skilled technicians and labour;
- some over-investment on machinery (to cope with major breakdowns, expensive spare parts or accessories from abroad);
- well-trained and skilled drivers and operators;
- wage incentive systems for different levels of management and workers to encourage efficient work;
- constant and growing demand for products, to permit high production (capital costs will grow if production goes down);
- reasonable buffer stores of all the hard-to-get commodities (fuel, lubricants, additives, standby generators, etc.).

Appendix 1

A. SERVICE BOOK, TRACTOR NO. CW 3747

Date	Time	Mechanic	Description of work	Costs (Shs)
4.8.83	16.00-17.00	William	Puncture, rear tyre	75
7.8.83	11.30-13.30	William	Weekly service	300
12.8.83	7.00-8.00	Shoo	Adjustment of brakes	75
14.8.83	7.00-12.00	William	1100-h. service	1 355
			- change oil and filter	
			- change diesel filter	
			- change oil in air filter	
			- change fanbelt	
etc.				

B. SERVICE COSTS FOR TRACTOR NO. CW 3747

Month	Mach.hours End of period	Maintenance costs (Shs)			Remarks
		Spares	Labour	Total	
Jan. 83	55	2 455	715	3 170	First 50-h.service
Feb. 83	127	375	1 570	1 945	Building safety frames for tractor
March 83	166	290	500	790	New replacement wire for winch. Front tyre damaged, new placed.
April 83	233	940	580	1 520	
May 83	301	1 300	400	1 700	
		etc.			
Total	760	14 500	9 300	23 800	

Unit maintenance and repair costs for the year 1983 are as follows:

Spares $14\,500/760 = 19.1$ Shs/mach.h.
 Labour $9\,300/760 = 12.2$ Shs/mach.h.
 Total $23\,800/760 = 31.3$ Shs/mach.h.

Appendix 2

TRAINING COURSE FOR NEWLY EMPLOYED TRACTOR OPERATORS

Objectives

The main objectives are to give the participants general knowledge of how an agricultural tractor functions and the basic skills needed to operate the machine in the forest.

Skills

After the course the successful participant will be able to do the following:

- describe how the Otto engine and diesel engine work;
- identify and describe the function of the components of a simple hydraulic system consisting of tank, pump, filter, relief valve, control valve and work cylinder;
- describe the function of the transmission system;
- describe the function of the brake system;
- carry out the servicing and simple repairs normally done by the operator;
- drive the machine safely on public roads and in the forest;
- be aware of his role and responsibility as driver and understand his role in the logging chain.

Time distribution

Subjects	Time allocation			Remarks
	Theory	Practice	Total	
1. Introduction, background and objectives	3		3	
2. Engine science	6	7	13	
3. Transmission system	3	2	5	
4. Hydraulic system	3	3	6	
5. Pneumatic system and brakes	1	1	2	
6. Winches and cables	2	1	3	
7. Maintenance and repairs	3	5	8	
8. Safety and ergonomics in logging operations	2	1	3	
9. Traffic laws and rules	2	-	2	
10. On-the-job training (driving, planning of work, maintenance and repair, report writing, safety, fire fighting)	4	36	40	3 participants/ tractor
11. Practical test in fault-tracing, maintenance and driving techniques)	-	8	8	Driver's certificate
Total	29	64	93	

Appendix 3

EXTENSION COURSE FOR LOGGING TRACTOR DRIVERS

Skills

After completion of the course the driver is able to do the following:

- carry out the daily and weekly maintenance himself;
- carry out small repairs himself in the forest and judge when the tractor has to be taken immediately to the workshop;
- understand the task work method used in log transport;
- understand the idea of log volumes (m³) used in task work calculations and estimate the volume of each load.

The conditions for attending this course are that the driver has a valid driving licence, he has successfully attended the basic course for drivers, and his work during the practical training period has been satisfactory.

Time distribution

Subjects	Time allocation, hours			Remarks
	Theory	Practice	Total	
1. Introduction, background, objectives	1		1	
2. Production records, task work method, volumes	4	6	10	
3. Common work problems experienced by drivers	1	2	3	
4. Engine science, transmission, gearbox	2	4	6	
5. Brakes, tyres, winches, cables, etc.: normal faults	2	12	14	
6. Service and maintenance	2	12	14	
7. Repairs done by driver	2	12	14	
8. Practical test in fault tracing	1	4	5	
9. Practical work test		8	8	
10. Safety and ergonomics	2	5	7	
Total	17	65	82	

Note: It is strongly emphasized that this training consisting of two courses and a practical training period is really crash training and the absolute minimum for logging tractor drivers.



Bucking stems with a bowsaw. Production in felling
and bucking with bowsaw and manual extraction
in steep terrain averaged 2.7 m³ per man/day
(Mutare Board and Paper Mills) (Photo: H. Seppänen)

GENERAL PRINCIPLES OF FOREST ROAD NETS

by

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1. INTRODUCTION

Forest truck roads form the basic investment for forest utilization throughout the world. Trucks transport timber directly from forest landings to the mill at relatively low cost both in the coniferous forests of the northern hemisphere and in tropical forests.

Despite wide differences in natural and economic conditions, there are some common principles of general road layout:

- Depending on local conditions and forest inventories, forest roads and interrelating timber harvesting systems demand integrated planning.
- Whether it covers entire watersheds or logging concessions, a general road plan has to concern itself with individual road projects. Therefore, plan from the general to the particular!
- As a defective layout is irreversible after the roads have been constructed, errors are critical. Only qualified and experienced engineers in close cooperation with local staff who are familiar with the forest area guarantee a well-planned network.
- Designed for heavy loads but low speeds and low traffic density, forest roads have different standards and specifications from public roads.

2. STANDARDS AND SPECIFICATIONS

2.1 Forest development schemes

Frequently located on non-forested land, access roads connect a forest area as well as the traversed agricultural land and settlements to the public road net (Fig. 1). Consequently, access roads have primarily "lengthwise functions", and serve for external development.

In Europe, most of these access roads are already constructed as rural public roads. In tropical countries with limited funds for rural development, the rural road network to some extent consists of forest roads, since the utilization of the forest resource yields short-term economic returns.

The real forest road net inside the forest area has primarily "crosswise functions" and serves for internal development.

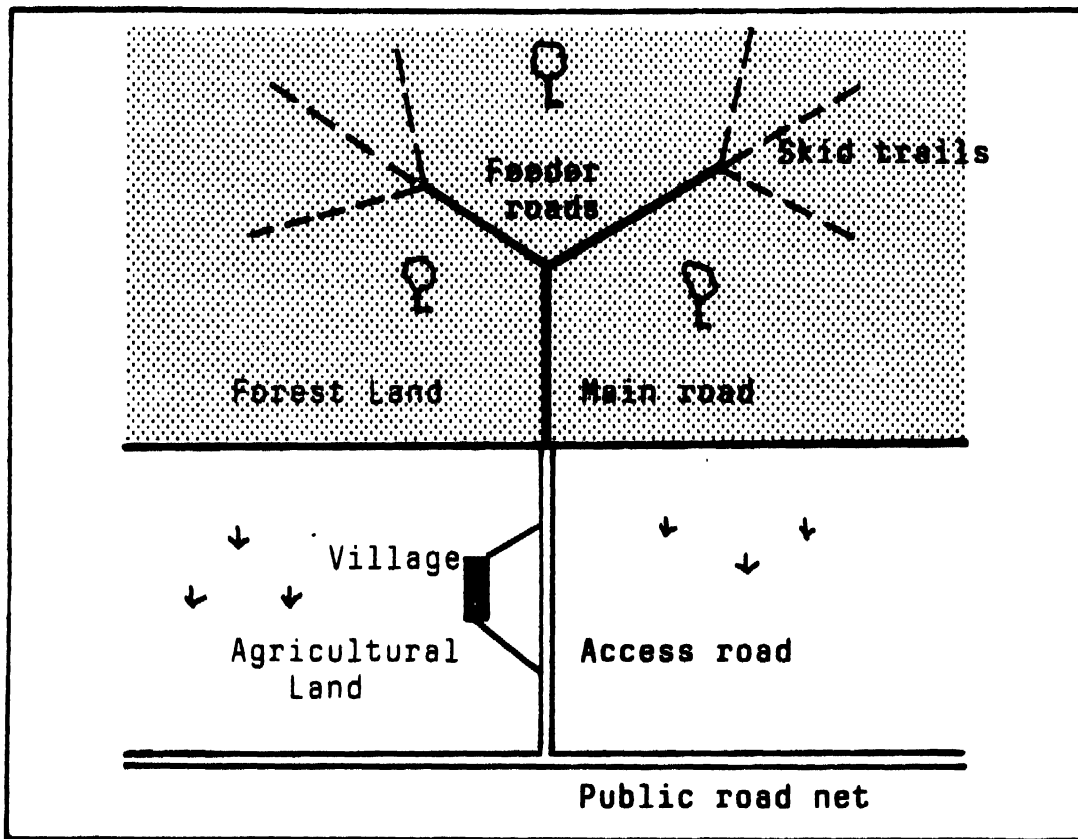


Fig. 1 ROAD NETWORK SCHEME

2.2 Road standards

The forest road network usually consists of three categories:

- Main roads with a solid base of gravel or coarse rock, usable by trucks the year round. Normally, these are all-weather roads, except in extremely wet periods;
- Feeder roads with or without a partial base. As fair-weather roads, they are usable by trucks only during the dry season;
- Skid trails which are simple earth roads connecting stump sites and road landings, usable by skidders during the dry season.

2.3 Forest road specifications

Fig. 2 shows a cross-section with minimum dimensions required for a main road. Based upon international experiences in mountainous terrain, specifications of forest roads are given in Table 1.

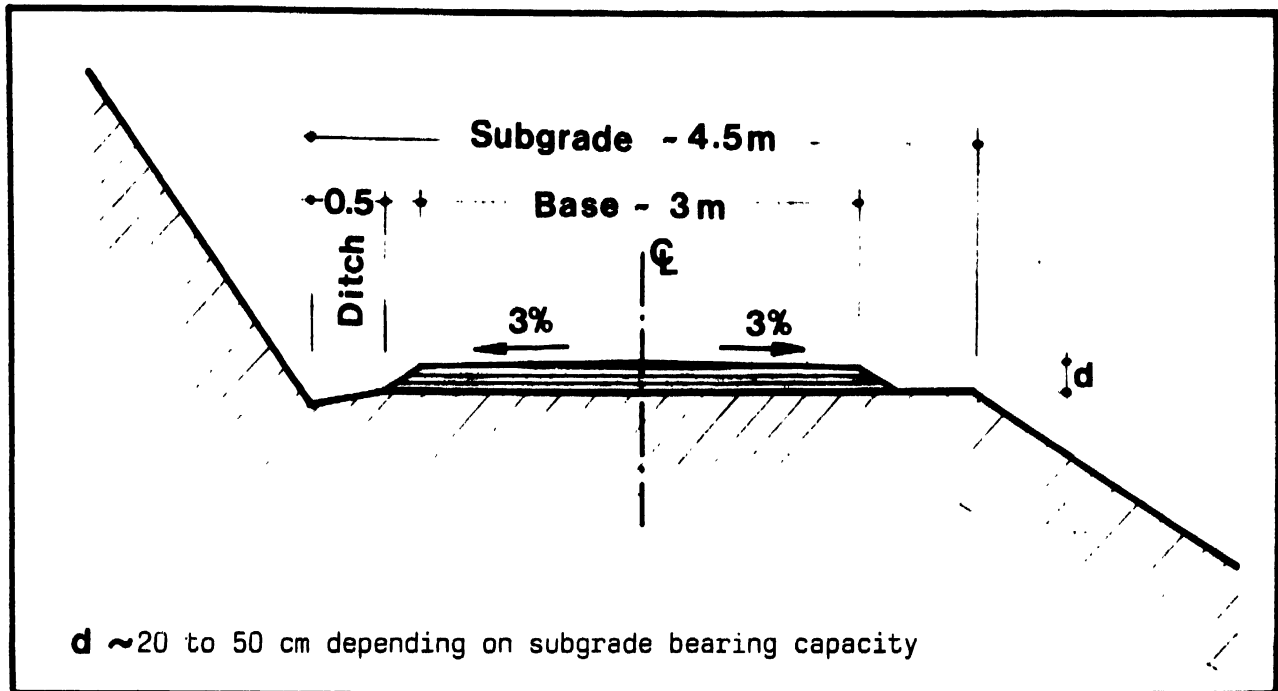


Fig. 2 CROSS-SECTION OF A FOREST TRUCK ROAD

Table 1

SPECIFICATIONS OF FOREST TRUCK ROADS

Specifications	Slope grade <60%	Slope grade >60%
Width of subgrade	4.5 to 5.5 m	4.0 m
Width of base	3.0 to 3.5 m	3.0 m
Minimum radius	20 m	15 m
Maximum gradient	9 to 10 (12) percent	
Minimum gradient	2 to 3 percent	
Maximum adverse grade	6 to 8 (10) percent	
Switchback radius	10 m	
Switchback grade	5 to 6 percent	
Switchback lane	6 m	

3. PARAMETERS OF FOREST ROAD NETWORKS

3.1 Road density

Road density (RD) is expressed by the ratio of truck road length to developed forest area:

$$RD = \frac{l \text{ (m)}}{a \text{ (ha)}}$$

RD figures indicate the degree of forest development, and they are applied to general comparisons in statistics. Tables 2 and 3 show some data from Central Europe.

Table 2

RATING OF RD IN CENTRAL EUROPE (PRODUCTION FORESTS)

RD (m/ha)	Intensity of development	Forest category and type of ownership
< 20	low	Large estates with highly mechanized logging systems
20 to 40	medium	Average conditions
> 40	high	Small farm holdings, low mechanization

Table 3

ACTUAL RD IN AUSTRIAN PRODUCTION FORESTS (1980)

Type of ownership	RD (m/ha) <u>1/</u>
Small private forests	38
Private forest estates	31
Federal state forests	27

1/ Figures include public roads within the forest area.

It should be emphasized here that general RD figures neither refer to local transport conditions nor are suitable planning inputs for individual projects.

3.2 Road spacing

Road spacing (RS) is the mean horizontal distance between the truck roads of a forest road network. RS refers to RD by means of the formula

$$RS (m) = \frac{10\ 000}{RD}$$

Depending on field conditions, actual road layout differs from the theoretical model of parallel roads. Therefore, correction factors are applied to adjust RS to actual conditions.

A correction factor of 1.25 for skidder country, for example, was determined by Abegg (1978):

$$RS_{act.} (m) = \frac{10\ 000}{RD} \times 1.25$$

Depending on model computations and local experience, figures of optimum RS are parameters for the general layout of a forest road network.

Table 4 shows average figures of RS, depending on terrain and forest type, for commercial forests. Overall figures have to be adapted to local conditions.

Table 4

ROAD SPACING DEPENDING ON TERRAIN AND FOREST TYPE

Slope grade	Terrain	Skidding system	Coniferous forests	Tropical forests
0 - 15 %	Level	Wheeled skidder uphill-downhill	~500-700 m	~1 000 m
15 - 30 %	Gentle - hilly	Wheeled skidder downhill	~500 m	~700 m
30 - 50 %	Medium, hilly - mountain	Skidder on trail, yarding	~300 m	~500 m
> 50 %	Steep, mountain	Yarding, gravity ground skidding	~400-500 m	~700-1 000 m (feasible)

3.3 Average skidding distance

The mean value of the skidding distance (s) within a forest road network depends on road spacing, terrain and the skidding techniques applied.

RD refers to s by means of a "road efficiency factor" (a) in Segebaden's formula (FAO 1974):

$$s \text{ (km)} = \frac{RD \text{ (m/ha)}}{a}$$

s average skidding distance (km)

a road efficiency factor:

4 - 5 flat terrain

5 - 7 hilly terrain

7 - 9 steep terrain

> 9 very steep, irregular terrain.

Löffler-Timminger (1974) and Abegg (1978) have carried out similar studies. The mean skidding distance in hilly country of Central Europe is determined by the equation

$$s \text{ (m)} = \frac{1.8 \times 2\,500}{RD}$$

This equation correlates to a road efficiency factor (Segebaden) of 4.5.

4. OPTIMUM FOREST TRANSPORTATION SYSTEMS

4.1 Direct and indirect effects of forest roads

In general, direct effects of forest road networks are:

- minimized cost and time for transportation;
- easy access to remote forest areas, which are connected to the public road net and to the market;
- impact of road construction on environment.

Direct road effects can be subdivided into economic effects, social effects on forest workers and personnel, effects on environment (soil, water, biotope) and effects on recreation. These direct effects are listed in detail in Fig. 3.

The direct effects on forest roads cause a multitude of indirect effects, e.g., effects on land use, population and environment.

These indirect effects, however, are neither cogent nor determined in advance. Whether and how they occur depend on man's follow-up activities after road construction. Forest roads, for instance, can lead to regular forest management, as well as to forest exploitation and destruction by intruders (shifting cultivation). Consequently, the socioeconomic setting of a country will mainly determine the effectiveness of forest development roads.

4.2 Procedures

As in most other human activities, the positive effects (benefits) of roads cannot be achieved without allowing for some negative effects (costs, in the broad sense). To select relatively the best option from several planning alternatives is the primary aim of the planner's procedures, ranging from simple cost estimation to system analysis.

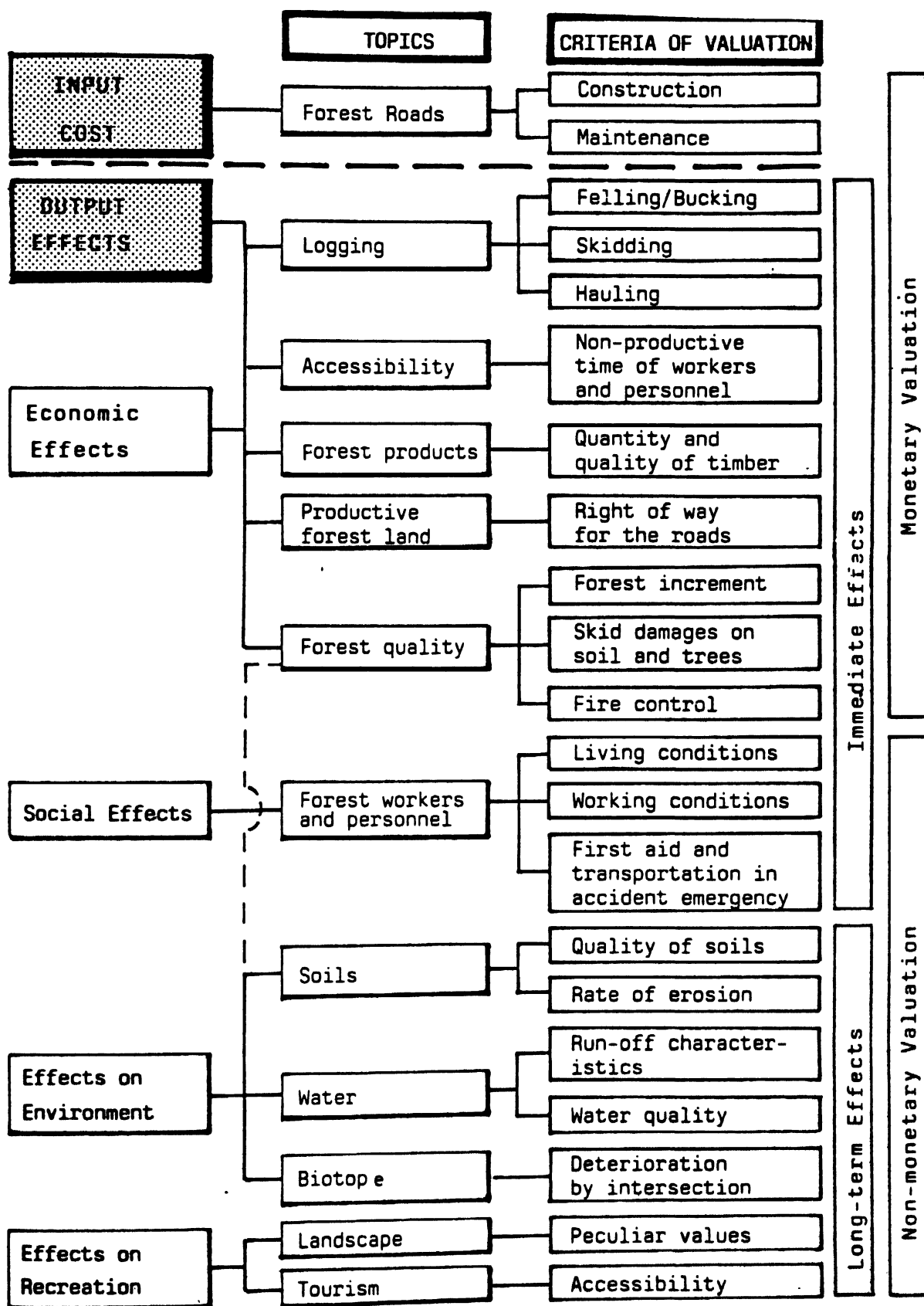


Fig. 3 COST-EFFECTIVENESS SCHEME OF FOREST ROADS

4.2.1 Monetary valuation

Monetary calculations put economic effects into focus. An analytical estimation of optimum road density (RD opt.) aims to minimize the interdependent total costs of on-road (truck) and off-road transportation. Fig. 4 shows the general correlation of road cost, skidding cost and total cost.

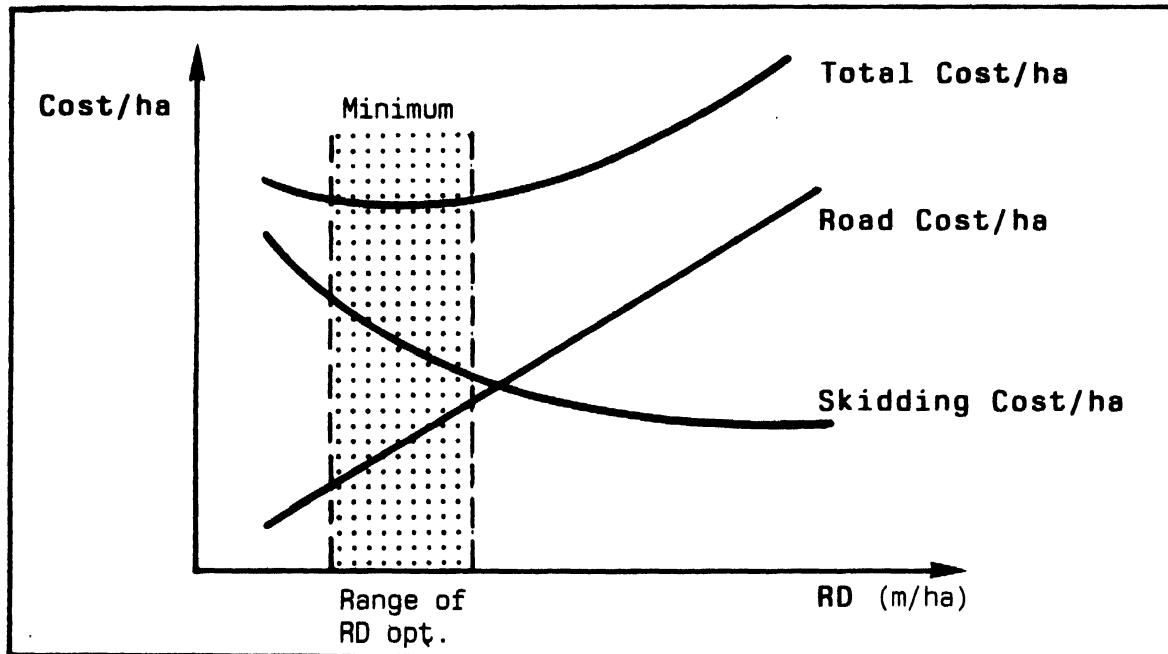


Fig. 4 ANALYTICAL SCHEME OF OPTIMUM FOREST ROAD DENSITY

Inputs of this method of narrow scope are:

- average annual forest yield;
- average skidding cost;
- average road cost (construction and maintenance).

By means of these input data, computations of RD opt. result in low figures of from 10 to 20 m/ha in commercial forests of Central Europe. Therefore, additional economic effects - for example, non-productive time of workers and personnel, and skid damage - should be taken into account for more reasonable results.

A comprehensive study by Abegg (1978) yielded RD figures of from 35 to 60 m/ha, depending on road cost of US\$ 50-130 per current metre of forest road in hilly country in Switzerland. This study proves the influence of additional cost parameters on RD opt.

Empirical procedures compare several project alternatives. A cost-benefit analysis of economic effects results in monetary benefit/cost-ratios, which facilitate selection of the best option.

4.2.2 Non-monetary valuation

Non-monetary effects, e.g., multiple-use management and impact on environment, cannot be quantified in monetary terms. They have to be valued by means of non-monetary parameters and procedures in transition to advanced system analysis.

A cost-effectiveness analysis, for example, compares effectiveness/cost-ratios of several alternatives, while effects (see Fig. 3) are assessed by means of non-monetary "values of effectiveness". This method is time-consuming and results are as precarious as inputs are variable.

Advanced system analysis of forest transportation systems is therefore at present only a topic of research in Central Europe.

5. LAND FORMS AND FOREST ROAD LAYOUT

5.1 Terrain classification

To a large extent, topographic features determine the layout of a forest transportation system. Terrain classification is therefore an essential planning element.

A macro description of terrain (Löffler, 1982) comprises:

- Macrotopography (land form) and drainage system
- Climate
- Geology
- Prevailing ground conditions
- Infrastructure (existing transportation system).

As long as international morphometric standards are not available, land forms and drainage systems are defined by means of topographic terms according to regional conditions. The best sources of land form information are modern topographic maps with contour-lines. Fig. 5 shows four sections of topographic maps (scale 1:50 000) which display land forms typical of Central Europe and southeast Asia.

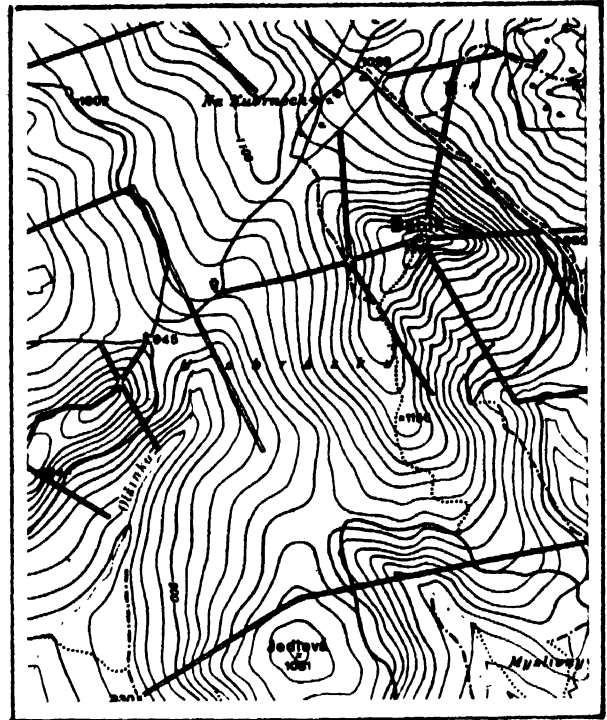
In order to classify smaller land units in detail, a micro description of terrain (Löffler, 1982) comprises:

- Ground conditions (soil strength)
- Ground roughness (or micro topography)
- Slope conditions
- Average skidding distance.

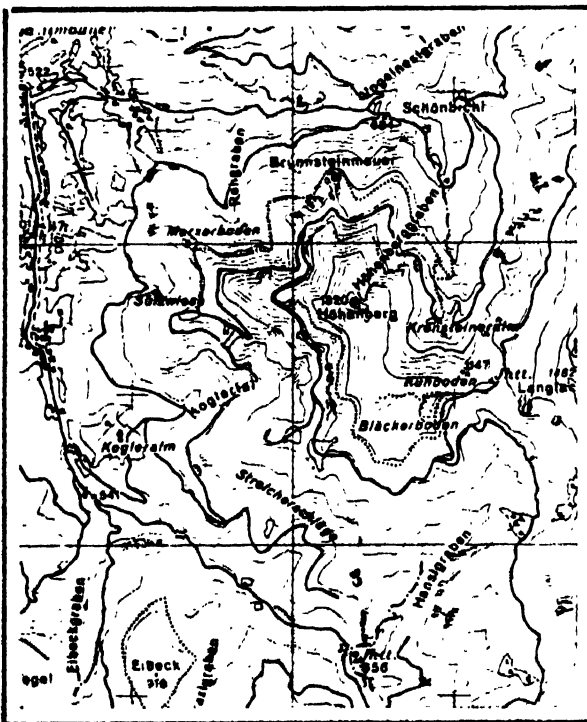
In particular, slope conditions (inclination and length) determine road layout and construction. Slope classes in mountainous country are described in Table 5.



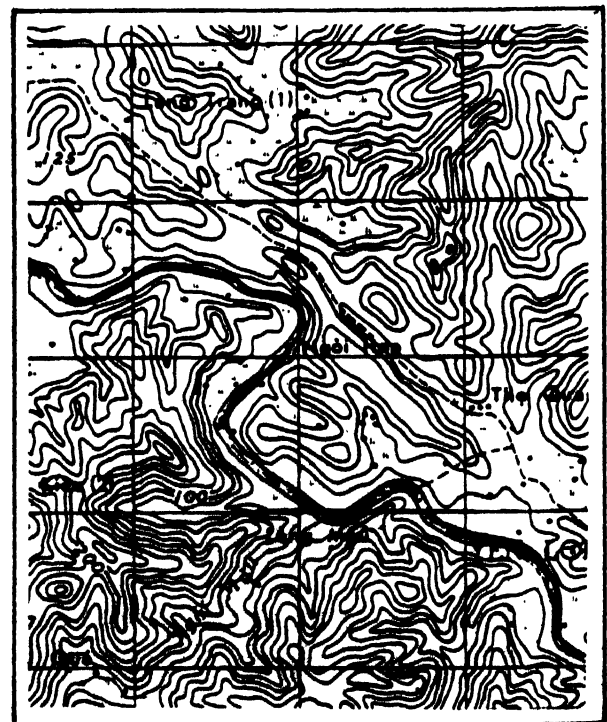
Level terrain with rectangular forest road network, Austria



Hilly to regular mountainous terrain with a forest road network of low density, USSR



Very steep, irregular, mountainous terrain with a forest road network of medium density, Austria



Hilly, very irregular terrain, northern Viet Nam

Fig. 5 SECTIONS OF TOPOGRAPHIC MAPS, SCALE 1 TO 50 000

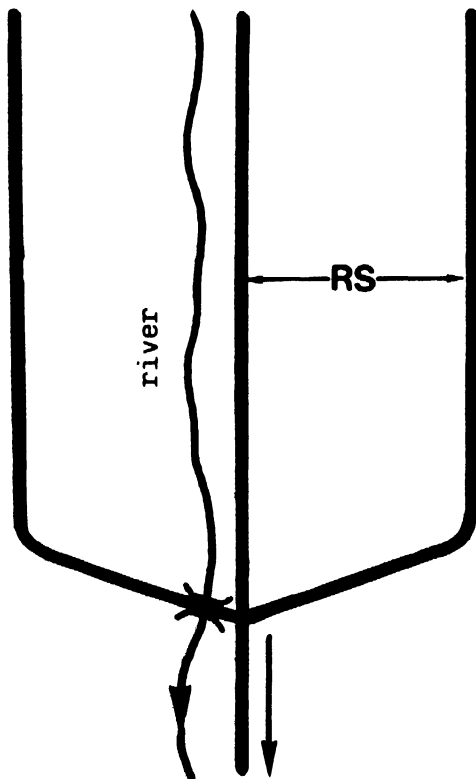
Table 5

INCLINATION AND SLOPE CLASSES

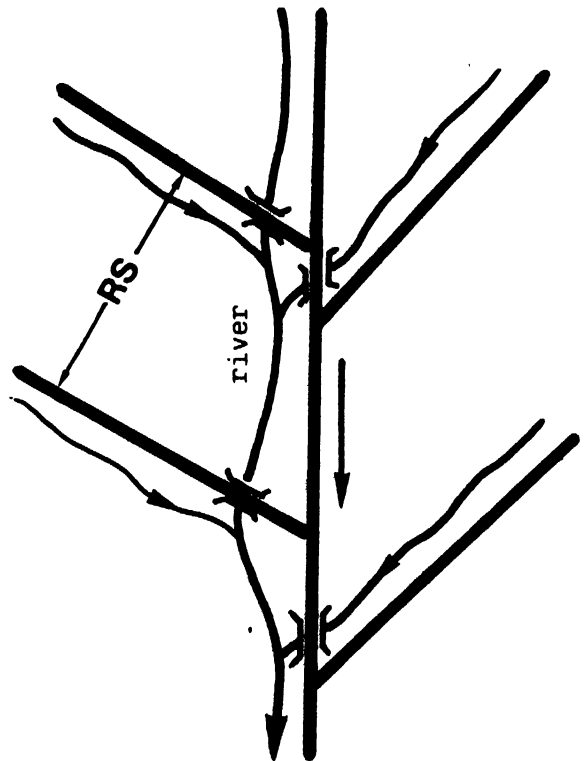
Slope grade	Slope class	Prevailing ground conditions for road construction
0 - 15 %	Level	Poor drainage, unfavourable
15 - 30 %	Gentle	Favourable
30 - 50	Moderate	Still favourable
50 - 70	Steep	Difficult, increasing proportion of bedrock
> 70 %	Very steep	Very difficult, rocky, roads feasible only over short distances

5.2 Road layout on level ground

Depending on the drainage system, road layouts of rectangular or chevron patterns are typical on level ground or in rolling country. Feeder roads are more or less parallel, with constant spacing (Fig. 6).



Rectangular Pattern



Chevron Pattern

Fig. 6 ROAD PATTERNS IN LEVEL AND ROLLING TERRAIN

Therefore, road nets in flat terrain correspond fairly well to optimizing models. In this easy terrain, skidder performance is good over distances of up to 500 m. On the other hand, poor drainage and low soil-bearing capacity hamper road construction and skidding. RS of about 500 to 1,000 m is recommended, depending on local conditions (see Table 4).

5.3 Road layout in mountainous terrain

5.3.1 General remarks

The general road layout should cover an entire watershed, which may consist of several sub-watersheds. Valley roads are the backbone of a road system in mountainous terrain. Branching off the valley roads, slope roads subdivide mountainsides into units for uphill or downhill skidding or yarding (Fig. 7).

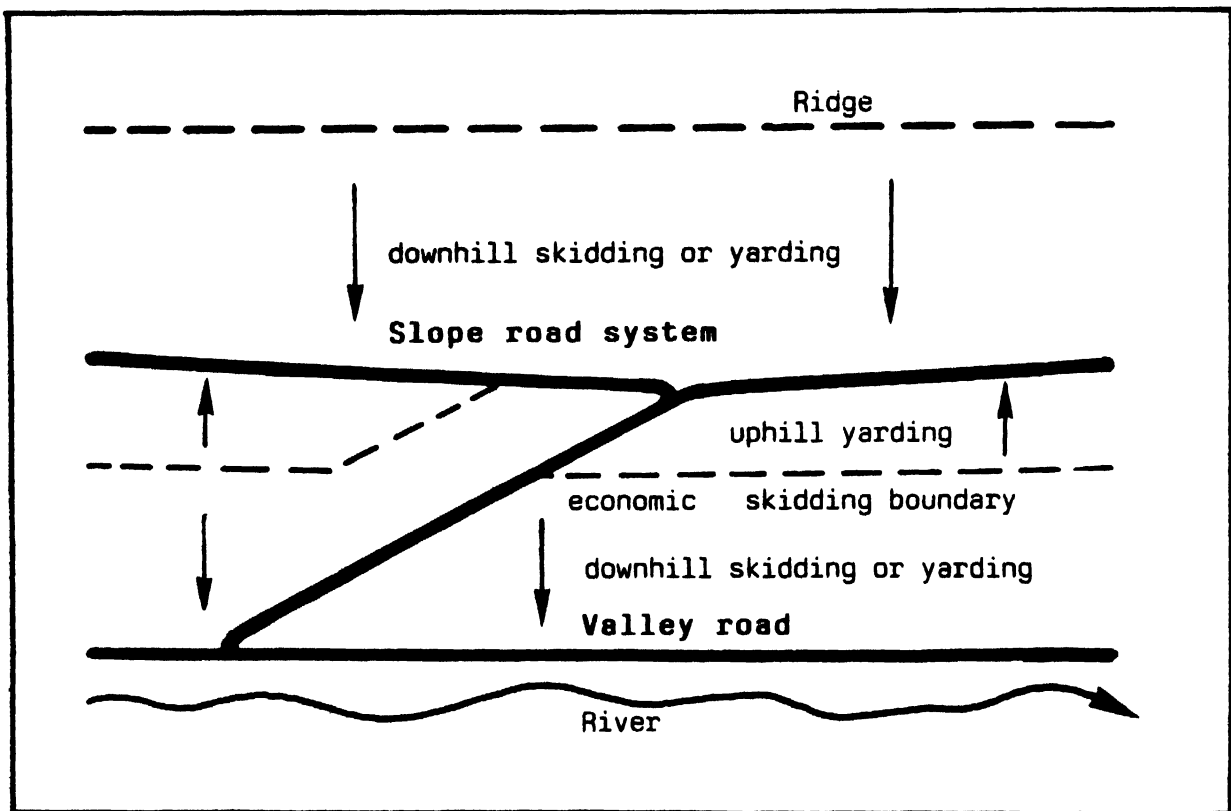


Fig. 7 VALLEY ROAD AND SLOPE ROAD SYSTEM IN MOUNTAINOUS TERRAIN

As far as feasible, the force of gravity should be used for timber transportation in mountainous country, since fuel costs are rising in the long run. Ridge road systems and adverse road grades should therefore be avoided as far as possible.

5.3.2 Valley roads

As they collect the transport flow from several slope roads, valley roads are usually main roads.

Valleys in mountainous country are frequently too steep to be directly followed by the road. Figs. 8 - 10 show features of valley road layout.

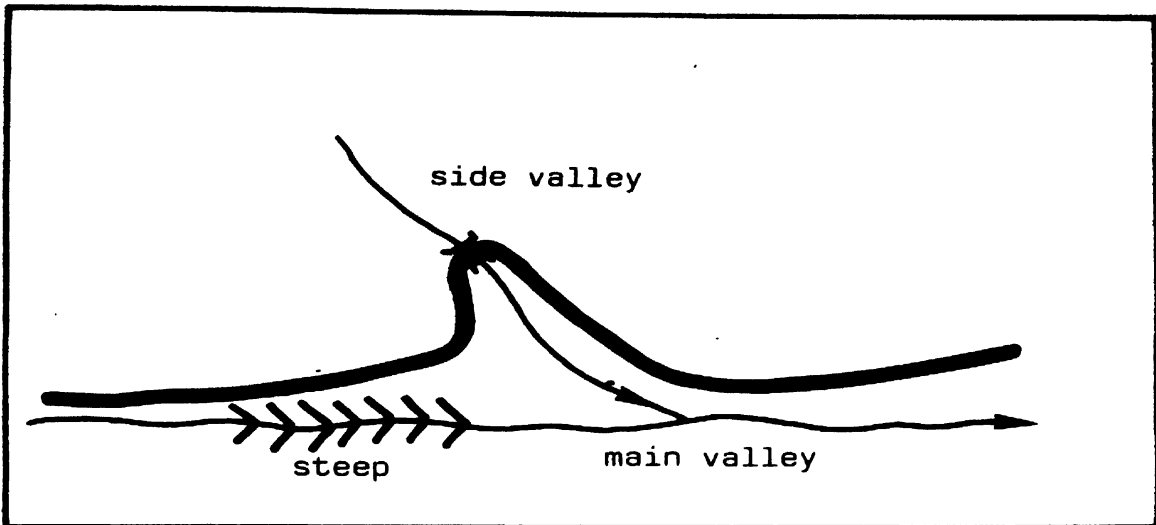


Fig. 8 ROAD WITH SIDE VALLEY CURVE

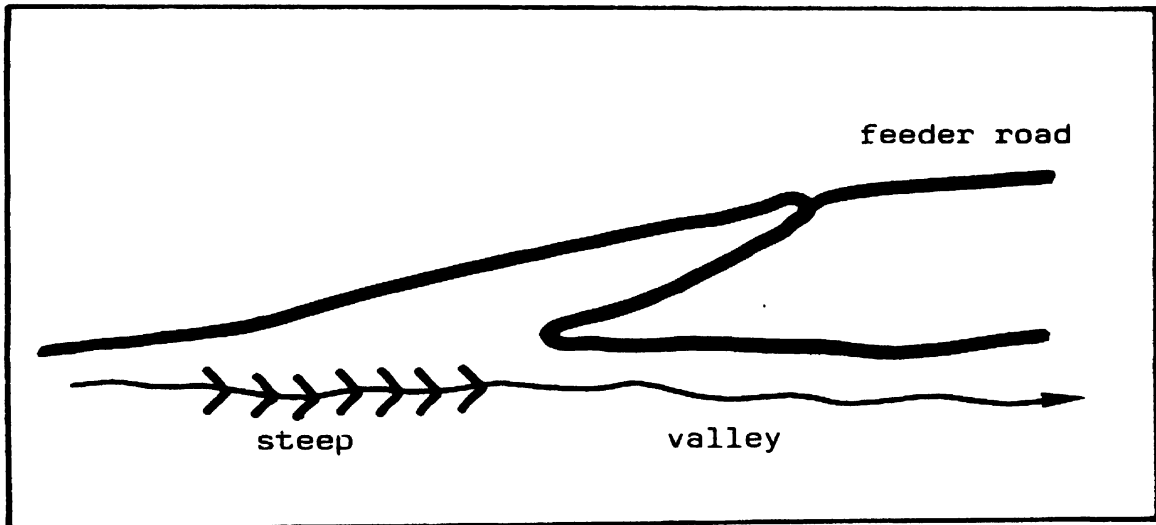


Fig. 9 SERPENTINE SLOPE ROAD

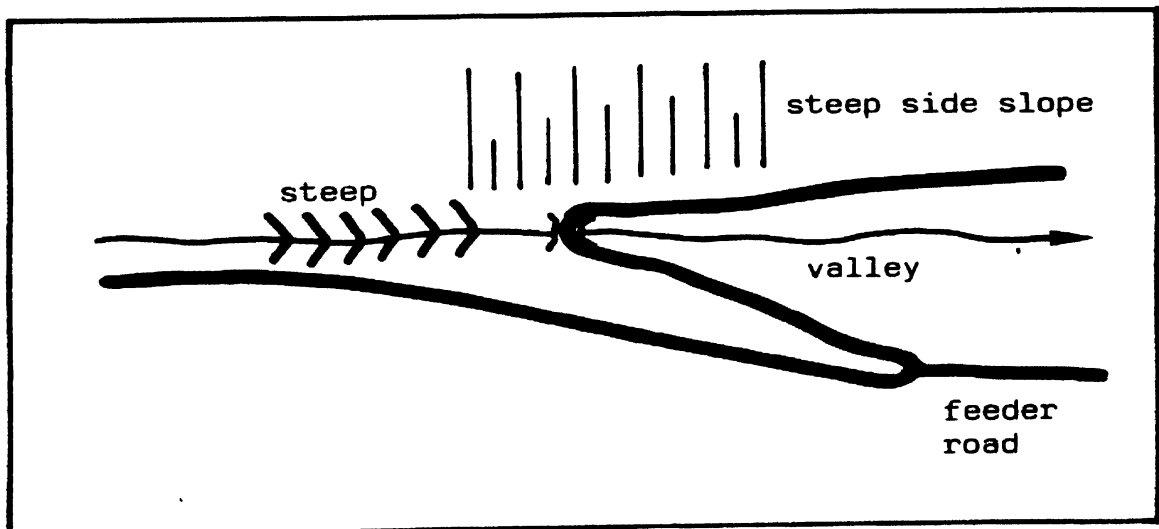


Fig. 10 SERPENTINE VALLEY ROAD WITH BRIDGE

5.3.3 Slope roads

Diagonal road systems with a rather steep main branch and gentle side branches are feasible on gentle to medium slopes (Fig. 11).

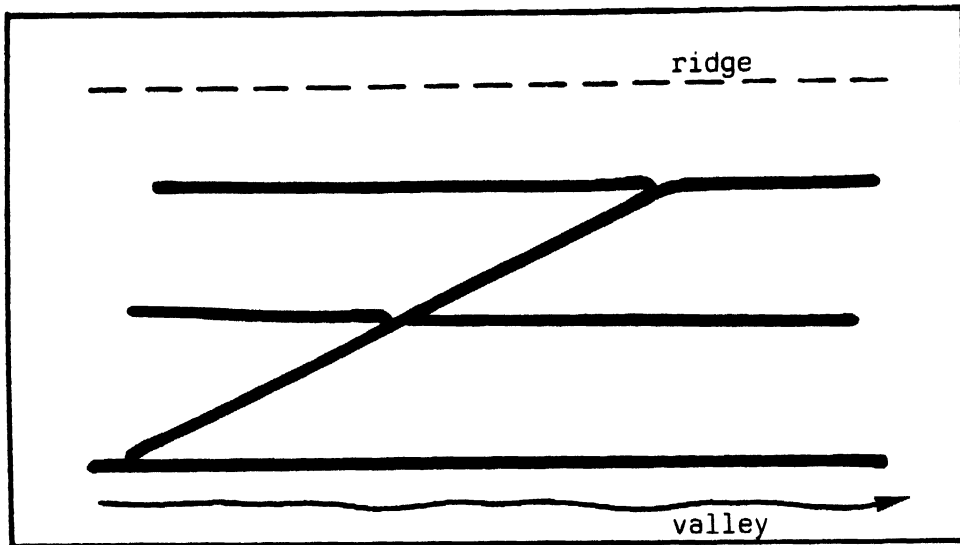


Fig. 11 DIAGONAL ROAD SYSTEM ON GENTLE SLOPE

Serpentine systems are required on steeper slopes (Fig. 12). However, switchbacks are costly and have a negative impact on terrain and environment. Their number in a road system should be minimized and their location must be carefully planned.

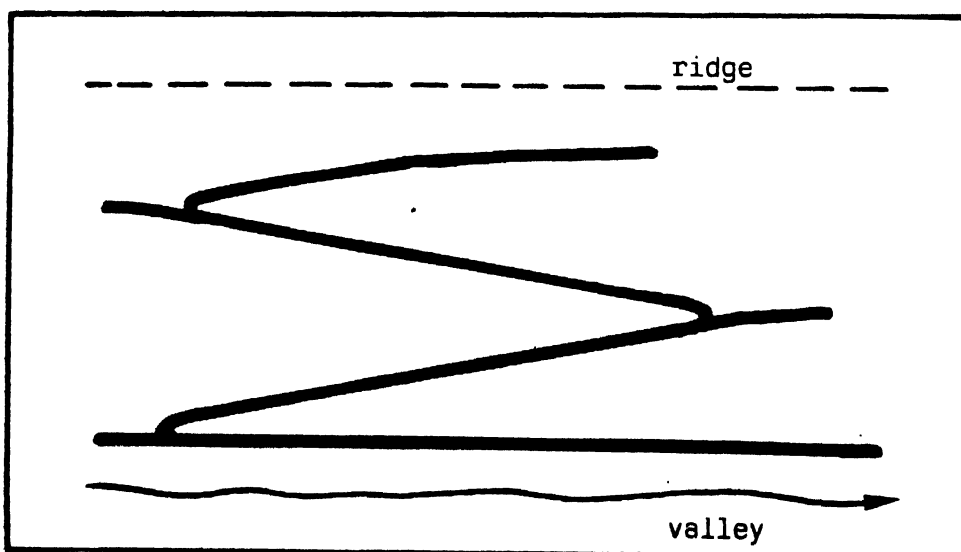


Fig. 12 SERPENTINE SYSTEM ON STEEP SLOPE

Zigzag patterns with avoidable switchbacks over short distances (Fig. 13) are extremely disadvantageous and indicate poor planning.

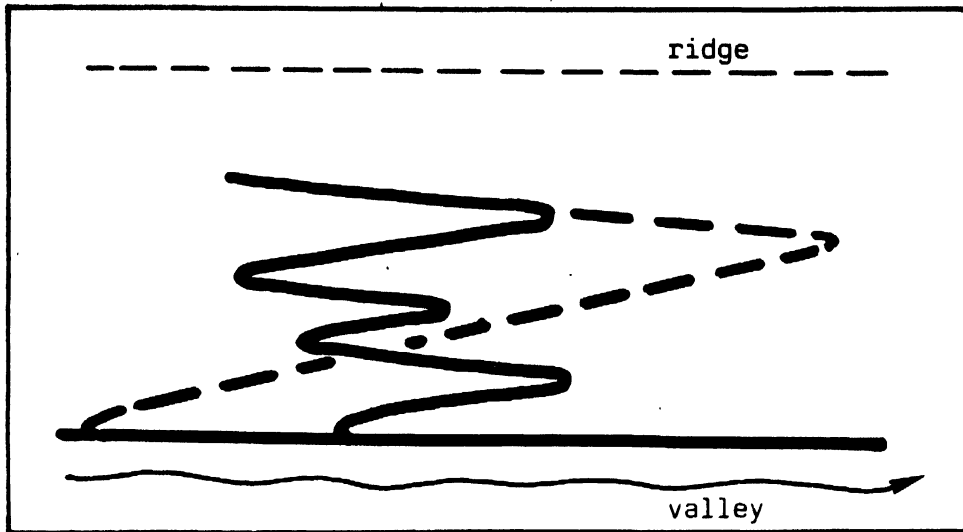


Fig. 13 ZIGZAG PATTERN AND CORRECT ALIGNMENT

5.3.4 Ridge roads

If valleys are inaccessible and/or slopes are very steep or unstable, a ridge road system may be a feasible option. Ridge roads open up forest areas to only a limited extent, however, they are a typical layout pattern for uphill yarding systems, e.g., high lead (Fig. 14).

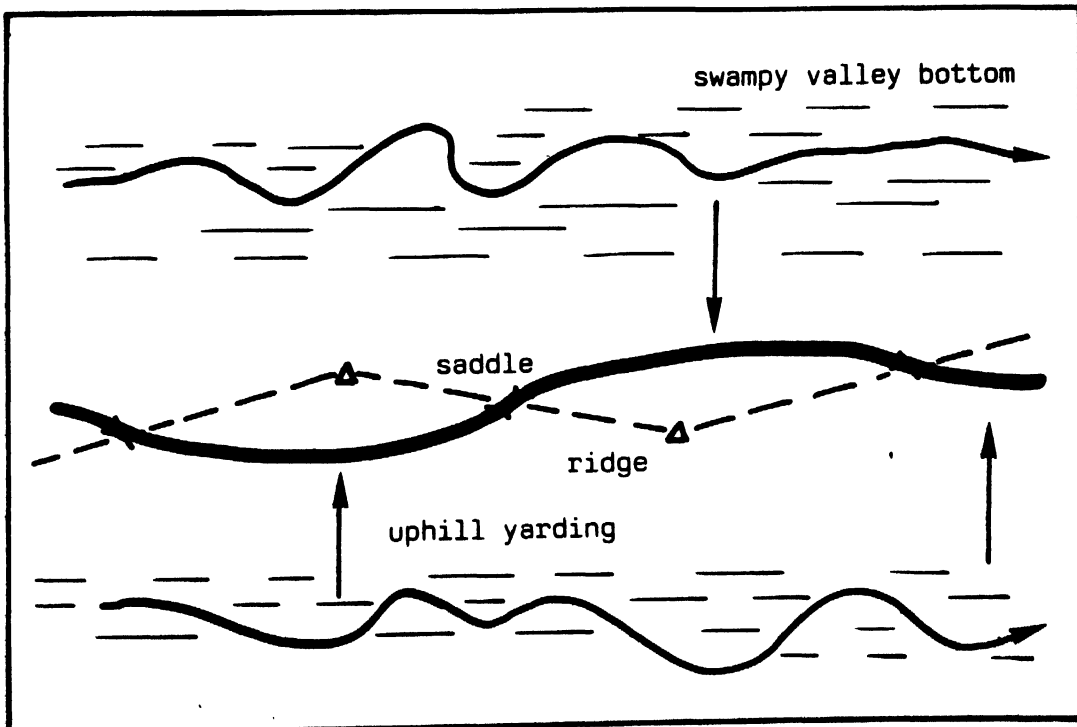


Fig. 14 RIDGE ROAD BECAUSE OF INACCESSIBLE VALLEY BOTTOMS

5.3.5 Valley basins

Mountainous watersheds frequently form valley basins with several steep creeks or ravines. A main road on the valley bottom combined with a circular slope-road system properly opens up this land form (Fig. 15).

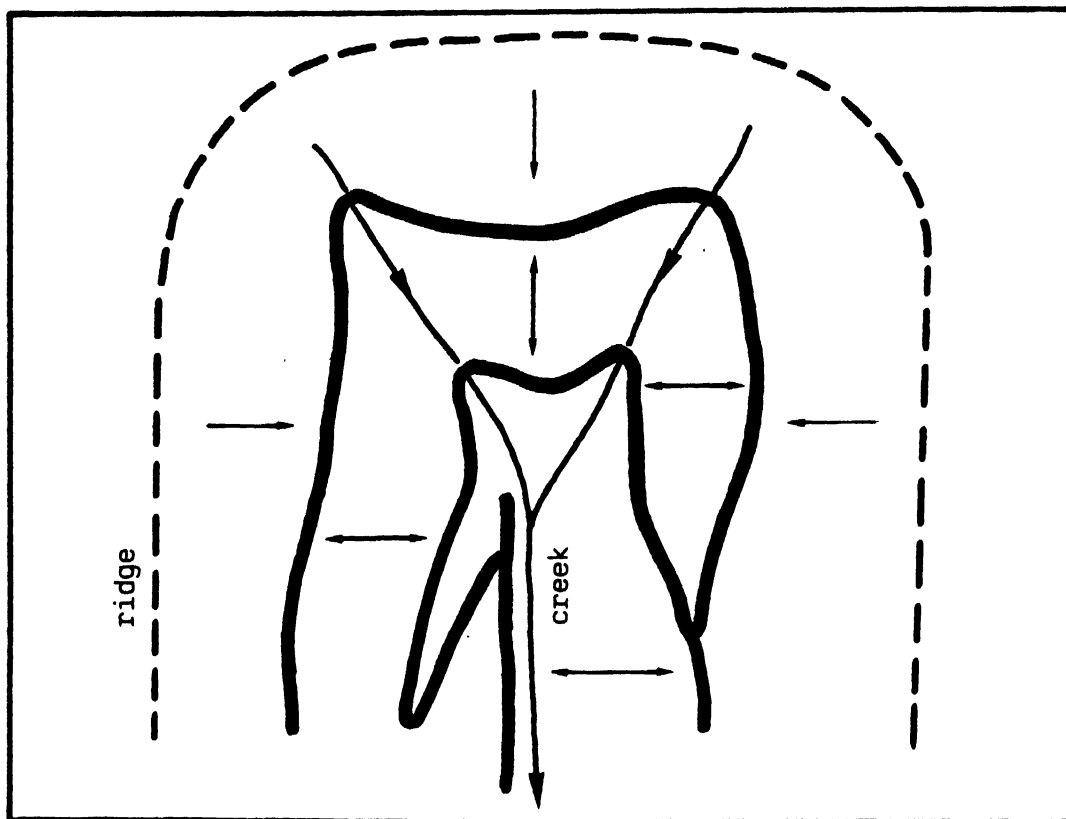


Fig. 15 VALLEY BASIN DEVELOPMENT

6. PLANNING RECOMMENDATIONS

6.1 Preliminaries

Comprehensive information drawn from maps, forest management plans, transportation planning, experiences of previous road construction in the area and so on, are prerequisites for a reconnaissance survey for the most feasible road network. Some topics are discussed below.

6.1.1 Aerial photographs

Available worldwide today, aerial photographs are an excellent source of pre-reconnaissance information, although they cannot compete with modern topographic maps for engineering purposes.

If topographic maps are not available, aerial photographs of level terrain may be used as "photomaps" because they show true distances.

In order to use aerial photographs of mountainous country in the same way, this imagery has to be transformed to "ortho-photomaps" by means of modern photogrammetric procedures.

6.1.2 Topographic maps

Derived from evaluation of aerial imagery, modern topographic maps are nearly indispensable for overall planning studies in large areas. Usual scales are 1:25 000 or 1:50 000 with vertical contour intervals of 20 m.

6.1.3 Special maps

Forest maps (scale 1:5 000 or 1:10 000, preferably with 20-m contours) show topographic details as well as timber cover, age classes, existing transport system, land ownership, etc. These large-scale maps are suitable for more detailed drafts or road layout.

Geological maps show formations of parent rock and subsoil conditions.

Hydrological maps show characteristics of the drainage system and precipitation zones.

Hazard maps indicate sensitive areas endangered by impacts of peak-floods, erosion and landslides, mud-flows, etc.

6.2 Field reconnaissance

Planning a forest road network is an iterative process which involves field reconnaissance alternating with office work. The importance of a thorough field survey, personally conducted on the ground by the engineering staff, cannot be over-emphasized.

Organization and timing of the field survey have to be carefully planned in advance. Field work in tropical areas should as far as possible be carried out during the dry season.

The initial field reconnaissance is a more or less cursory examination of predominant land forms and control points, the drainage system, forest cover, ground conditions, existing road system and working conditions.

The second stage of the preliminary survey comprises provisional office drafts of likely, feasible main route alternatives, preferably on copies of the topographic map, scale 1:25 000, or on the forest map, scale 1:10 000.

In order to verify these preliminary route projections, a thorough field survey of the presumed road corridors is the most important planning stage. The terrain is traversed, alternate routes are examined on the ground, and control points are determined by means of barometric altimeters.

Positive control points are, for instance, suitable crossings of rivers, saddles on ridges, benches for road junctions, switchbacks and landings.

Negative control points are obstacles such as rock outcroppings and cliffs, very steep side slopes, landslides and swampy ground.

It is recommended that trial lines be run to locate feasible road corridors on the ground. In mountainous country, where roads are grade-controlled, the grade lines of the main routes are marked on trees with plastic flagging ("flag lines" of brightly-coloured plastic ribbons). Alternate routes are marked with different colours.

During this presurvey, the most feasible route corridors can as a rule already be determined from the technical viewpoint. The final road layout should, however, be cooperatively selected by the road engineering team, the local forest staff, and specialists on forest resources, environment and multiple land use. Inter-disciplinary planning should not be merely a trendy slogan but should be applied in practice for balanced results.

Where private estates are concerned the land owners play a major role in route negotiations.

6.3 Instruments

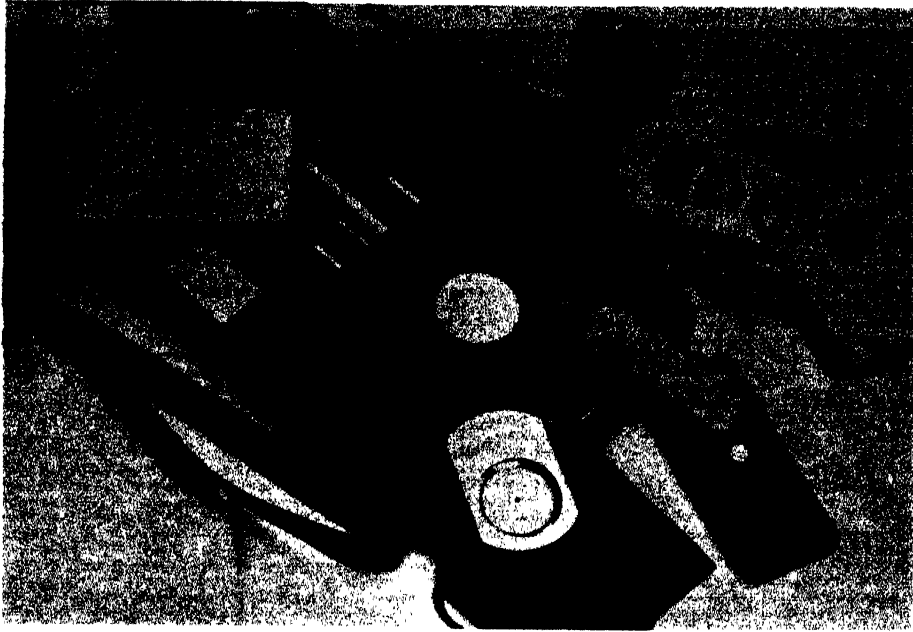
Modern hand-held instruments, small but accurate, have replaced theodolites and levelling instruments in forest road engineering, especially in mountainous terrain.

The following instruments and equipment are recommended for forest road location:

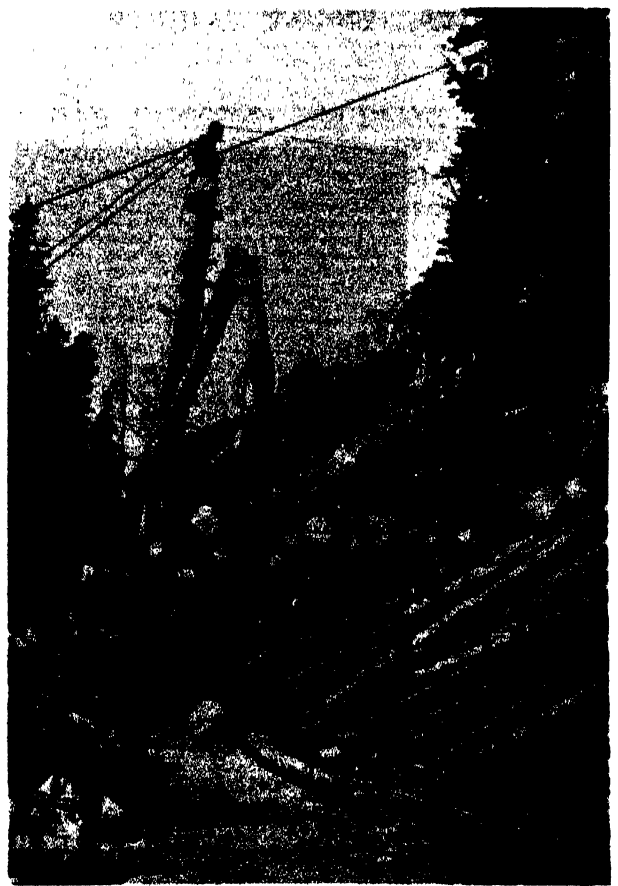
- Barometric altimeters, e.g., Thommen, Paulin
- Clinometers, e.g., Meridian, Suunto
- Compasses, e.g., Suunto, Meridian, Bezard, Silva
- Drag rope, 50 m, nylon
- Pocket stereoscope.

REFERENCES

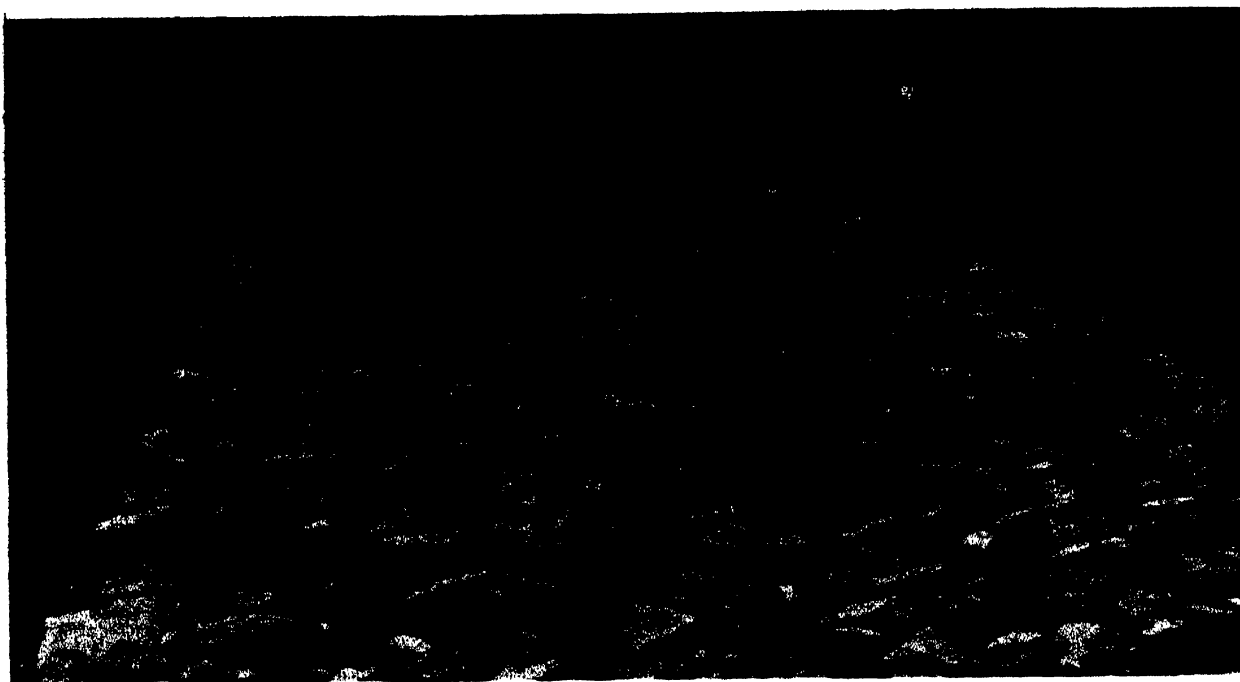
- Abegg, B. Die Schätzung der optimalen Dichte von Waldstrassen im
1978 traktorfahrbaren Gelände, Birmensdorf.
- FAO Logging and log transport in tropical high forest, Rome.
1974
- Löffler, H. Terrain classification and its relation to operational methods,
1982 ECE/FAO/ILO/IUFRO report, Norway.
- Löffler-Timinger Nutzen-Kosten-Untersuchung über den forstlichen
1974 Wirtschaftswegebau, Munich.



Engineer's wallet with instruments for road survey.
(Photo: O. Sedlak)



The result of planning - modern forest truck roads in hilly and
steep terrain facilitate logging and forest management.
(Photo: O. Sedlak)



Base of hand-pitched stones
(Photo: O. Sedlak)



**Timber-crib revetment for embankment construction
across a ravine (Photo: O. Sedlak)**

GENERAL INTRODUCTION TO FOREST ROAD CONSTRUCTION METHODS

by

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1. INTRODUCTION

Economic development after the second world war promoted a breakthrough in rural construction in Central Europe. Mechanized forest-road construction started with imported earth-moving machines in the early fifties.

Diversified machine equipment such as bulldozers, tracked loaders, excavators of various types, rock drills, dumpers and motorgraders reduced the initially high amount of additional manual labour to a minimum in transition to fully mechanized performance.

However, these highly mechanized capital-intensive systems are normally not an appropriate option for developing countries with different socioeconomic conditions. Where there is a lack of capital, and underemployment, imports of machinery for rural road construction should be limited as far as feasible in favour of manual labour for the benefit of the rural society, and locally available intermediate technology.

Forest roads differ from public roads in many respects. As private hauling roads with low traffic volume, they are usually low-cost roads used also for landing and processing logs. Their design and standards are determined by economic considerations depending on the local forest management system.

2. APPROPRIATE TECHNOLOGY

2.1 Wage levels and mechanization

Wage levels and rate of employment should be considered as important criteria of forest development roads.

There is a wide gap between wage levels of developing countries (approximately US\$ 1-10 a day) and industrialized countries (approximately US\$ 25-40 a day). On the other hand, prices of modern machine equipment and fuel are fairly similar worldwide in monetary terms (US\$). Therefore, imported machines are relatively expensive in developing countries. Despite a general trend to use machines even in countries with extreme rural underemployment, labour-intensive methods are a more appropriate option here.

Depending on local conditions, human labour and machine equipment should be combined to create balanced work systems that use domestic resources and meet economic and social needs in the best way.

2.2 Planning and organization

Independently of the level of technology applied, adequate planning and organization are basic prerequisites of proper forest road construction. Precise planning according to classical engineering rules (e.g., staking of the centreline, levelling, cross-section profiles, material balance) is advisable.

Grade line location is sufficient on slopes for partly or fully mechanized performance, because the major excavation and earth-moving is accomplished by machines. Consequently, road planners have to see engineering procedures and performance as interdependent.

Organization comprises work preparation as well as the road construction itself. Proper timing is of great importance in order to choose the season when local climatic conditions are most favourable for construction.

Labour-intensive performance is sensitive to big excavations in steep terrain, rock outcroppings, and transportation of material over long distances.

Manual work with numerous labourers also needs extensive preparation of many elements; for example, workers' camps, sanitary and medical facilities, supply of food and drinking water, equipment, and last but not least, recruitment and transportation of the labour force. Since work groups have to be established and well distributed on the construction site, work organization and supervision are extensive.

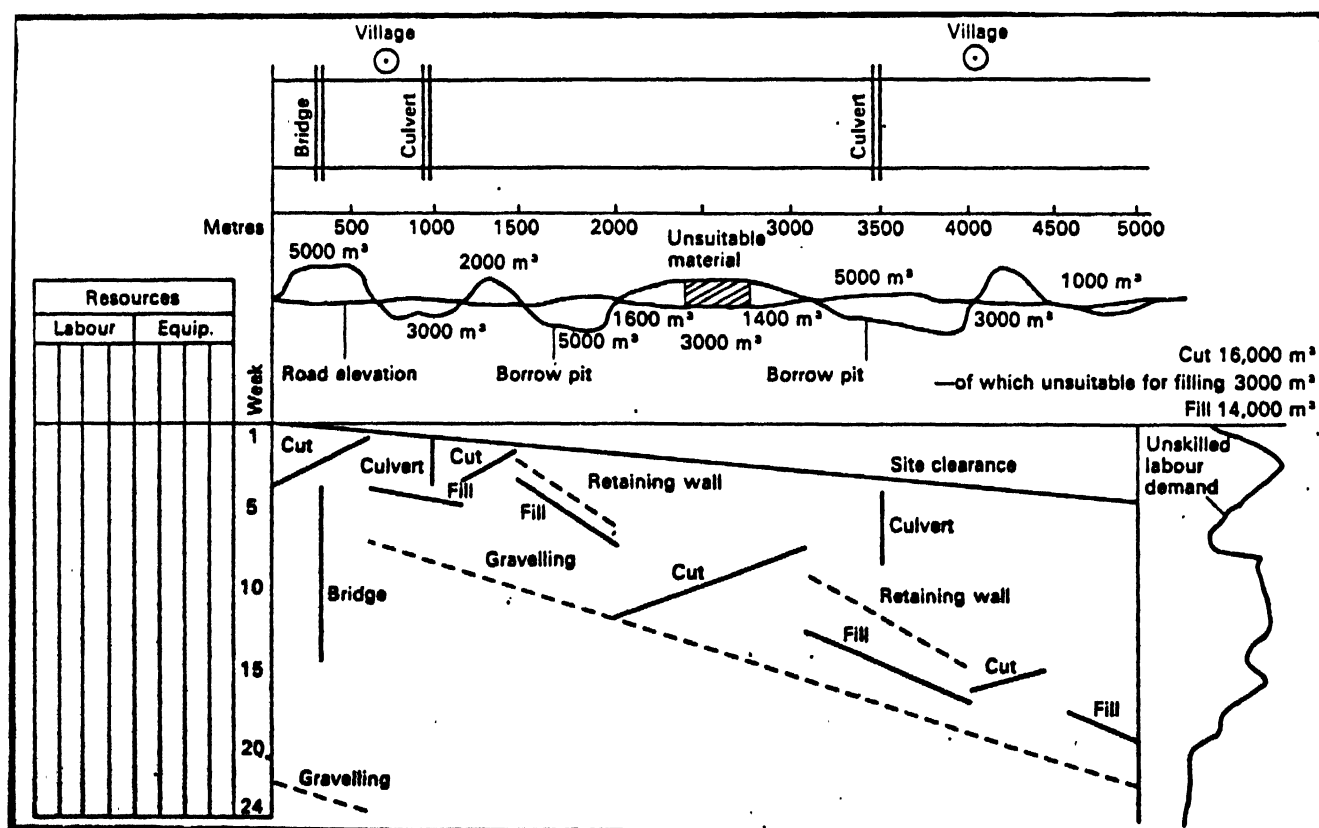


Fig. 1 TIME AND LOCATION CHART (Allal 1977)

Graphic charts of project components, time, and labour force are an excellent auxiliary instrument of organization. Fig. 1 shows a time and location chart (Allal 1977) that will indicate location, time, and labour demand in a diagram coincident with major road features.

Organizational problems for mechanized performance are different. Housing requirements on the sites are only marginal, but access and transport are more difficult because of machine dimensions and weights. The capacity of access roads and bridges as well as supply of fuel and explosives is frequently a critical bottleneck.

Experienced mechanics and spare parts are required on the construction site for extended operations in remote areas.

Machinery capacity has to be carefully determined according to the work system and site conditions in order to utilize the costly equipment fully and avoid idling.

2.3 Labour-intensive road construction

Manual road construction without any auxiliary equipment is the exception even in remote areas. It can, however, be an appropriate option in over-populated rural areas with underemployment and low wage levels, for instance, in southeast Asia.

Hand tools and wheelbarrows are frequently of inadequate quality and design. This basic equipment should meet ergonomic standards to increase output and to reduce workers' fatigue. Copies of imported samples can be locally produced. Conditions and efficiency of manual labour can easily be improved by means of such inexpensive investments which are marginal compared with imported machines. Excellent guides in this field are FAO Forestry Paper No. 36, Basic technology in forest operations, and ILO's Manual on the planning of labour-intensive road construction.

Fig. 2 (Allal 1977) shows a simple work scheme for the manual construction of a double-lane earth road on level ground. Such a road, for instance, could be constructed on favourable subsoil as a forest and village access road under a rural self-help scheme.

If the road is constructed by a constructor, workers are normally paid on a piece-rate basis, e.g., per cubic metre of subsoil excavated and moved. The individual output of work crews is measured daily by means of staked profiles.

More flexible are construction methods that combine manual labour and machines; for example, a bulldozer for the major earthwork and manual labour for complementary tasks.

2.4 Equipment-intensive operations

As already mentioned, highly mechanized forest road construction prevails in industrialized countries with high wage levels.

In Austria, for instance, hand labour accounts for less than 5 percent of the total forest road construction cost. Only two skilled men, the backhoe operator and an expert for rock drilling and blasting, work in fully mechanized operations in mountainous terrain. The investment in the machines is about US\$ 250 000 or US\$ 125 000 per caput of labour force! On the other hand, the building of culverts and timber revetments and seeding of cut and fill slopes are still to some extent carried out manually in farm forest development to provide the rural population with additional income from labour.

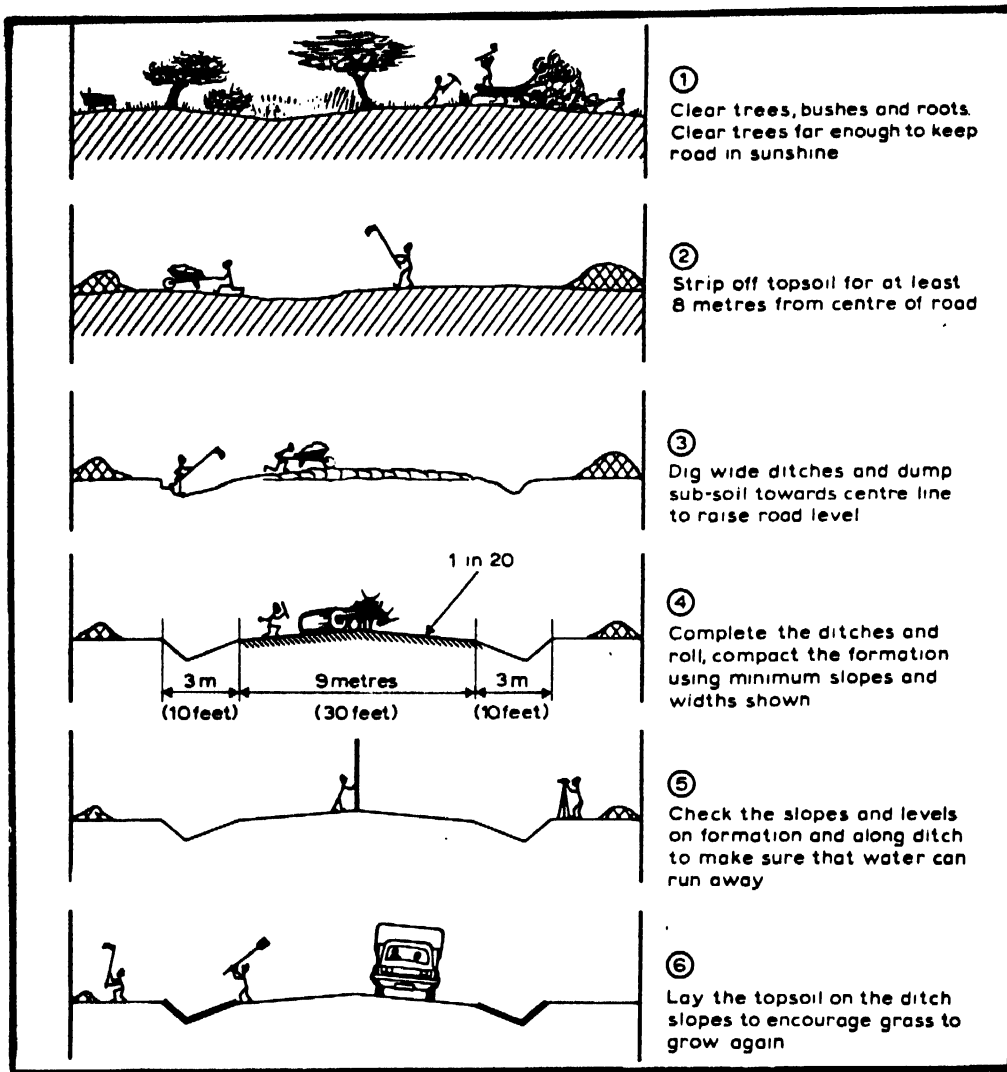


Fig. 2 HOW TO MAKE A SIMPLE EARTH ROAD (Allal 1977)

3. RIGHT OF WAY

3.1 Clearing limits

Right of way is the area claimed for forest road construction. Some space for roadsides is allowed and standing trees and underbrush must be cut down and removed to facilitate construction work. Clearing limits depend on cross-section profiles, side slopes and climatic conditions. Since moisture has a negative impact on roads, clearing limits of about 15 to 20 m in width on level ground in tropical rain forests nearly double limits in temperate forests in order to facilitate evaporation after tropical rainfalls.

Fig. 3 shows a typical cross-section along a side slope and gives terms used in road structure.

Depending on side-slope inclination, temperate-forest clearing limits (measured along the slope) of the cross-section profile indicated in Fig. 3 are given in a diagram (Fig. 4).

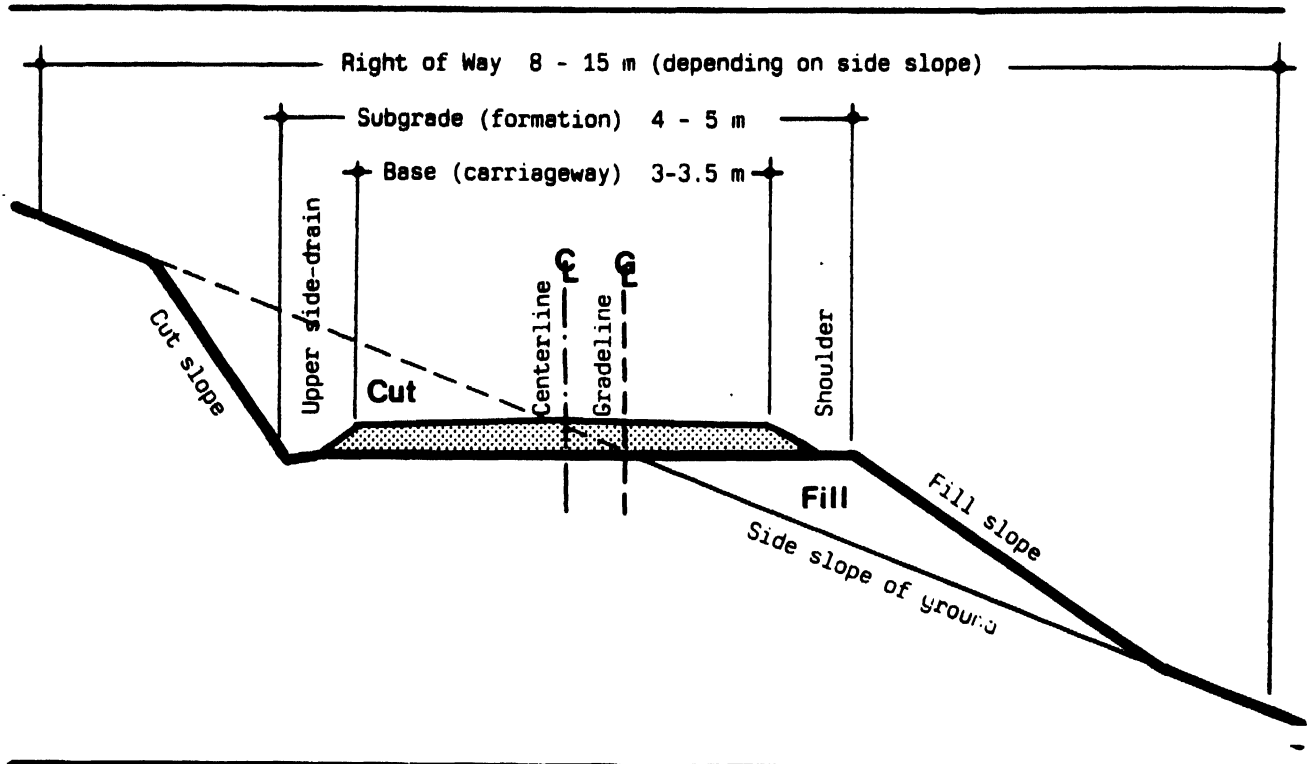


Fig. 3 TYPICAL CROSS-SECTION OF A SLOPE ROAD WITH TERMS USED IN ROAD STRUCTURE

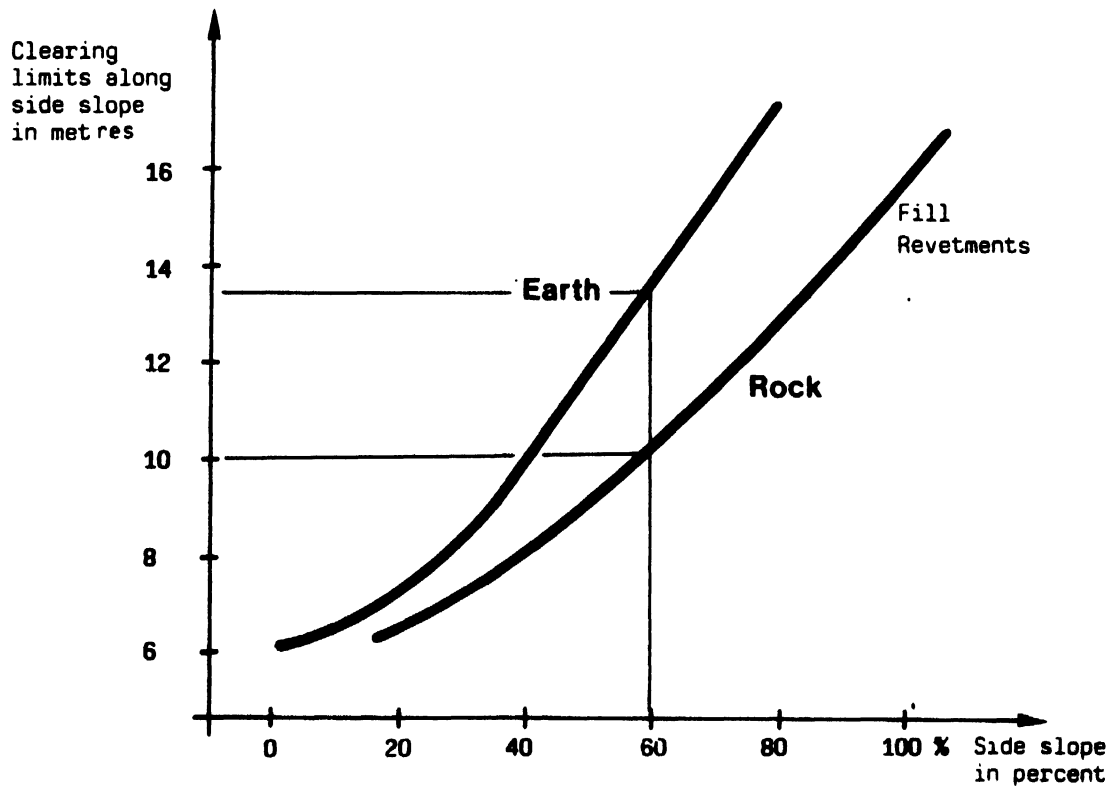


Fig. 4 DIAGRAM OF CLEARING LIMITS

3.2 Site clearing

The right of way for a forest road is a narrow strip, clearcut under rather difficult logging conditions. In easy terrain the timber is skidded off the construction site immediately after felling. Under difficult terrain conditions, however, the road corridor is only gradually accessible for skidding operations in front of the construction site. In steep terrain backhoes are an excellent means of hoisting whole trees on to the road subgrade from where a wheeled skidder drags the timber to landings. Skidding carried on at the same time hampers construction work and should therefore be restricted to conditions which are actually difficult.

After the usable timber has been removed, the road corridor has to be cleared of tops, branches and underbrush. This material should as far as possible be used as fuelwood. In steep terrain, however, it should be deposited at the lower edge of the corridor to protect the residual stand below the road against spoil debris.

3.3 Stump preblasting

If a bulldozer is used, big stumps within the formation should be preblasted to facilitate performance of the machine on level ground. On slopes only big stumps close to the gradeline have to be preblasted.

Heavy backhoes do not call for stump blasting because of their versatile working technique.

4. SUBGRADE CONSTRUCTION

4.1 Manual labour

Man's history proves that even huge earthmoving projects can be accomplished by means of manual labour only. If sufficient workers can be recruited, for instance, in densely populated rural areas, even long roads can be built in quite short periods, since several work groups are distributed along the construction site. As mentioned above, preparation and organization as well as the right equipment are prerequisites for economic performance.

It is advisable to keep the labour crews rather small to avoid impediments and idling within the groups. Primitive hoes, the sole agricultural tools in many countries, should be replaced in road construction by more efficient picks and shovels. The correct number of these implements for excavation and loading on soils of different properties has to be determined for each group.

Material should be hauled for short distances (up to 50 m) in wheelbarrows, preferably moved over planks to reduce rolling resistance. Small railway trucks, manually pushed on field rails, are an excellent hauling means for longer distances. Carrying heavy loads in head baskets or on stretchers should be avoided for ergonomic reasons.

4.2 Intermediate techniques

Intermediate techniques combine manual work with locally available machines and are an advisable option for rural road construction in developing countries. There are numerous alternatives, ranging from very simple equipment to specialized machines, which have to be arranged according to local conditions.

Example of low mechanization:

- Material excavation and loading/unloading by hand labour;
- Material transportation by agricultural wheeled tractor and trailer.

Example of medium mechanization:

- Material excavation by hand; loading/unloading, hauling and shaping by agricultural wheeled tractor with front-end loader and tipper trailer.

Example of high mechanization:

- Excavation, earth movement and shaping by a small bulldozer or tracked loader; cut slopes shaped manually.

4.3 Mechanized construction

4.3.1 Bulldozer performance

Bulldozers with hydraulically controlled angledozers or straight blades are the most economic earthmoving machines in forest road construction in industrialized countries, provided the side slope is not too steep. Performance and production depend to a high degree on the operator's skill and experience.

Table 1

SPECIFICATIONS OF BULLDOZERS EMPLOYED IN
FOREST ROAD CONSTRUCTION (Caterpillar)

Type	Operating weight (t)*	Truck gauge (m)	Engine	
			kW	Fuel consumption (l/h)
Light	15	1.9	80	20
Medium	18	1.9	100	25
Heavy	25	2.0	150	40

* Operating weight includes A-blade, ROPS, winch.

Medium machines with an operating weight of about 16 to 18 tons are sufficient for rural road construction. In developing countries these machines should be equipped only with naturally aspirated diesel engines (instead of turbo-charged engines) and with direct drive (instead of power shift), having regard to facilities for maintenance and repair. A rear winch and a rollover protective canopy are advisable in steep terrain. On level ground a rear ripper-scarifier instead of the winch may be an economic alternative. On wet ground with low bearing capacity crawler tractors with wide track shoes and low ground pressure should be employed.

Frequently, too heavy (and expensive) bulldozers are used in developing countries. Although such big machines have enormous reserves, in fact neither are they necessary nor can their production capacity be economically utilized in

rural road construction with limited space and material volumes. On the contrary, machine capacity should be reduced in favour of better vocational training of the operators.

Bulldozers have a high production in excavation and sidecasting along side slopes, but dozing distances should not exceed 30 to 50 m. Moreover, crawler tractor production is very sensitive to adverse grades. Work organization therefore has to provide for downhill operation as far as possible.

A skilled operator is able to put subgrades and cut slope in an excellent shape (close to motorgrader quality) on gentle to medium slopes without rock outcroppings. On the other hand, because of uncontrolled dumping of material, bulldozer sidecasting on steep slopes is a major cause of erosion and negative impact on the environment. Since heavy backhoes have proved to give excellent performance to both technical and environmental standards, bulldozers are no longer an advisable option in steep terrain.

4.3.2 Tracked loaders

Equipped with a bucket and a double hydraulic system, these versatile machines are designed for excavating and loading; for example, in gravel pits during base construction. Operating weights of medium machines are about 12 - 16 tons with bucket capacities of 1 - 2 m³.

Although loaders are not dozing machines, they have been extensively employed in subgrade construction, especially on steep and rocky slopes, to move and deposit blasted material in a more controlled way than bulldozers can. They were an intermediate stage in forest road construction on steep slopes to reduce impact on the environment before heavy backhoes were employed.

If a loader is working mainly in subgrade construction, the machine should be fitted with a reinforced bucket and bulldozer track shoes for better traction.

4.3.3 Hydraulic excavators

Hydraulic excavators of various types have supplemented bulldozers in Central Europe since the early sixties. Versatile on the job, excavators shape slopes, excavate ditches and foundations, and lay culverts after the major bulldozer earthwork has been accomplished. This machinery combination is still an economic choice for normal terrain today.

On steep and rocky slopes, however, heavy backhoes have replaced bulldozers during the last decade, since their performance meets environmental and technical requirements on critical sites better.

Excavators of the backhoe type are normally employed in forest road construction. Medium machines used supplementary to bulldozers have an operating weight of about 17 - 23 tons. Heavy backhoes, however, should weigh not less than 30 tons.

Backhoe performance is completely different from that of a bulldozer. While a crawler tractor has to move to work, the excavator undercarriage is at a standstill during excavation. Therefore, excavator performance is not sensitive to adverse road grades. While an earthmoving bulldozer sidecasts and dumps material in a more or less uncontrolled way, the excavator, on the contrary, deposits excavated material and boulders into the road fill. Also, on steep sideslopes the backhoe constructs boulder revetments beneath the road.

Table 2

SPECIFICATIONS OF EXCAVATORS EMPLOYED IN
FOREST ROAD CONSTRUCTION (Caterpillar)

Type	Operating weight (t)	Truck gauge (m)	Engine	
			kW	Fuel cons.(l/h)
Light	17	1.90	70	12
Medium	24	2.45	100	17
Heavy	38	2.70	150	30

Fig. 5 shows a cross-section of typical backhoe performance in steep terrain. Stages of backhoe operation on a steep slope are illustrated in Fig. 6.

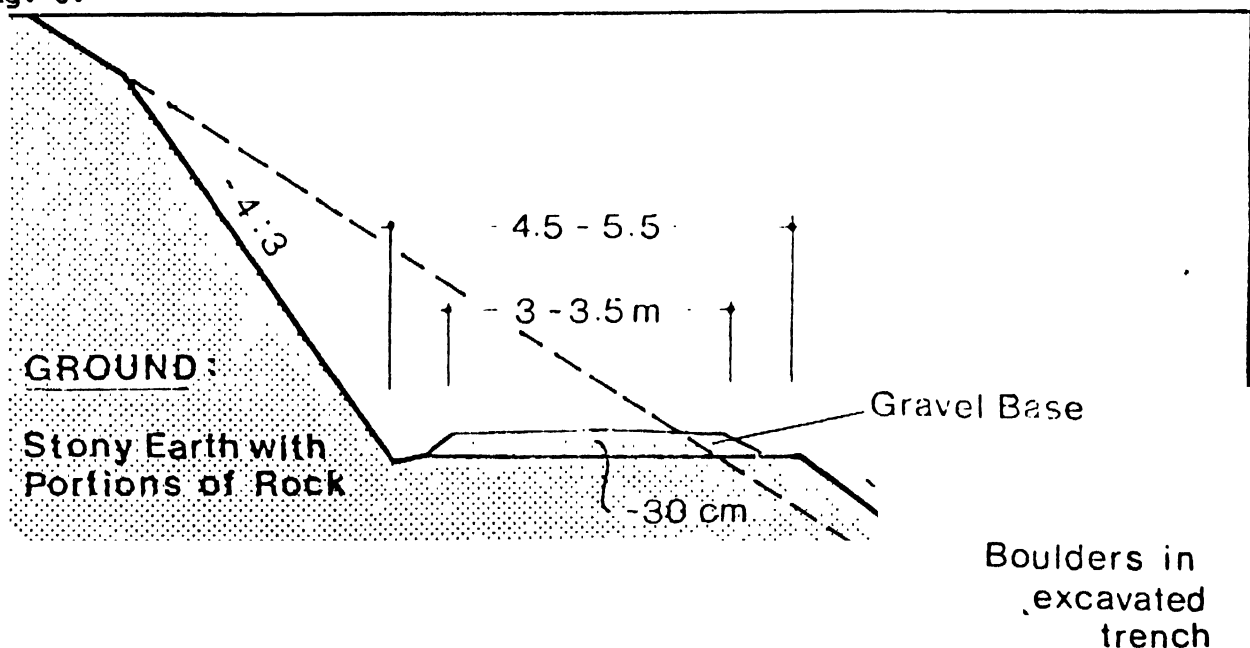


Fig. 5 CROSS-SECTION ON A STEEP SLOPE (Sedlak 1985)

4.4 Rock blasting

Manual rock drilling in hard rock by means of chisel and hammer is extremely time-consuming. This method should be applied only on small outcroppings of rock.

Mobile compressors-cum-hand-held pneumatic rock drills show an efficiency/-cost ratio adequate even in low-wage countries. This reliable equipment, which conforms to intermediate technology, is required for forest road construction in rocky terrain even in developing countries.

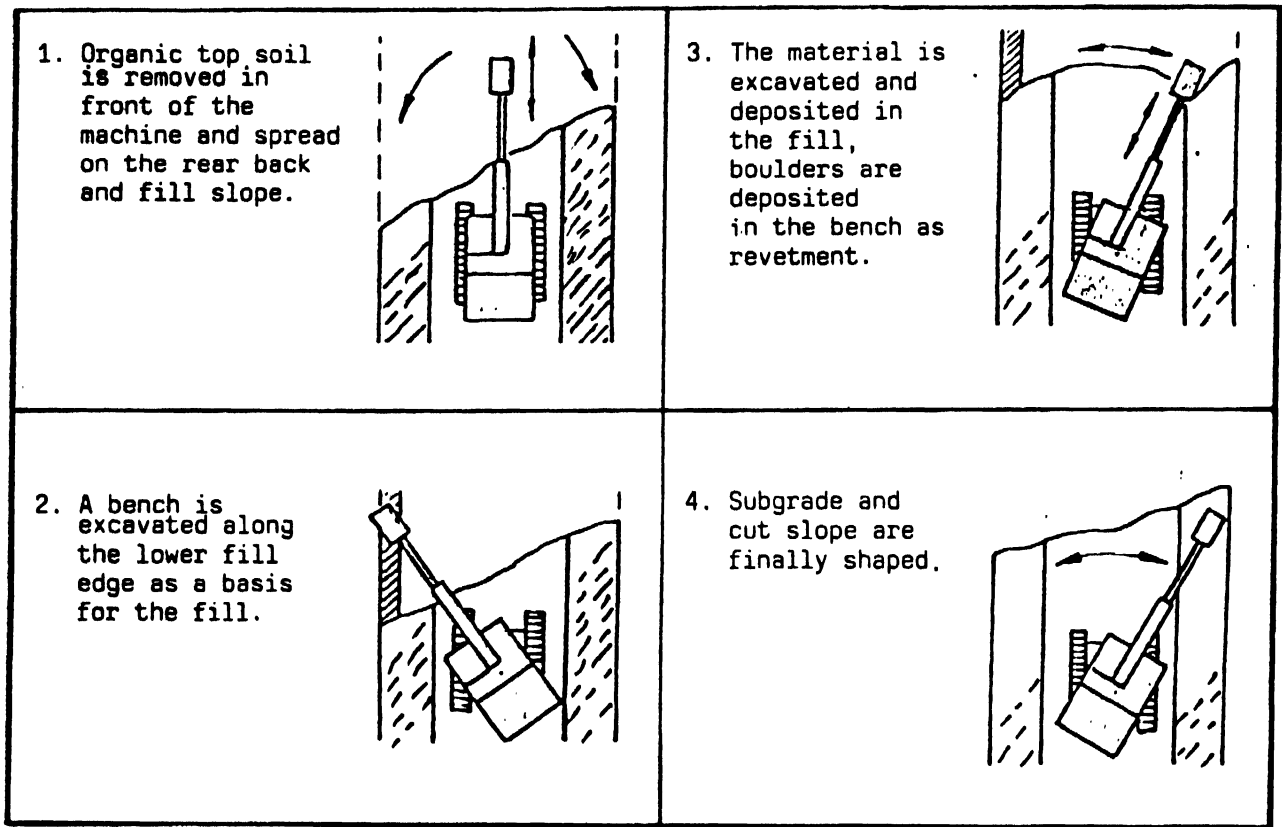


Fig. 6 BACKHOE OPERATION ON A STEEP SLOPE (Sedlak 1982)

The number and size of the pneumatic drills have to be adjusted to compressor capacity and vice versa. A small compressor has an output of about 2 m³ of compressed air per minute; a medium machine produces about 5 - 8 m³/min. Drill consumptions range from about 1 to 2 m³/min. Allowing for transmittal losses in hoses and couplings, a medium compressor will power about three drills, a small compressor only one. Fig. 7 shows installation schemes.

Only vertical holes should be drilled by means of hand-held drills because of ergonomic reasons. Depending on rock type and strata, the most economic drilling scheme has to be locally determined by way of trial (Fig. 8). If horizontal holes are required, the drills should be supported by means of planks or pneumatic devices.

Fully mechanized rock drilling is the rule in industrialized countries today. The job is done by only one man who operates the machine and carries out the blasting.

Mounted on different carriers (crawlers, wheeled tractors, excavators or integrated units) pneumatic or, more recently, hydraulic drilling machines drill mainly horizontal holes parallel to the road centreline (Fig. 9). Two major types of machine drills are available, internal or external drills with different diameters.

A well-trained and experienced foreman, usually the machine operator himself, has to be in charge of the blasting operations. He is responsible for handling explosives and safety on the site. In order to avoid accidents electrical ignition is strongly recommended for both manual and mechanized work.

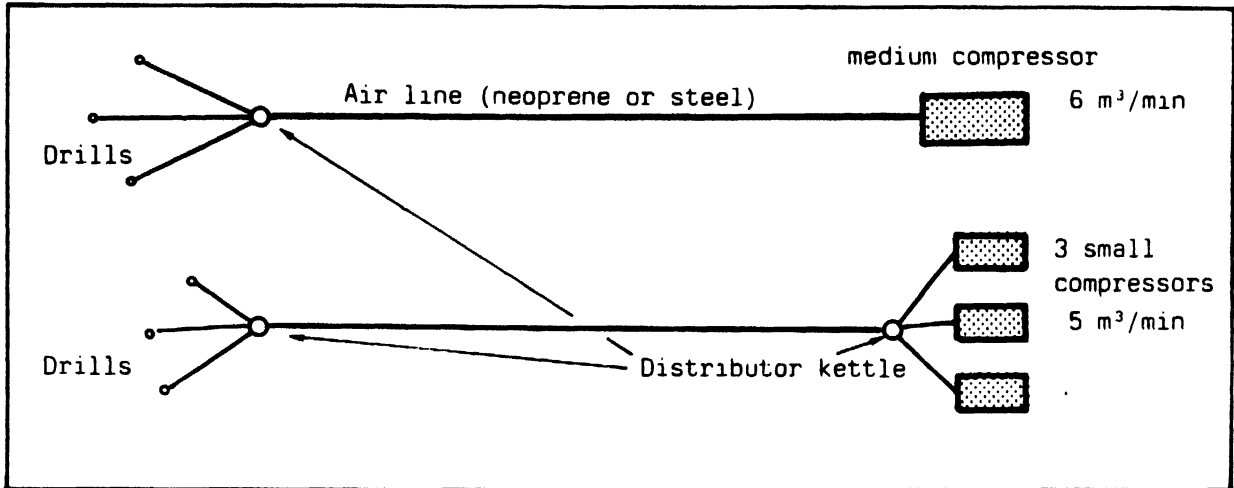


Fig. 7 COMPRESSOR AND DRILL INSTALLATION (GROUND VIEW)

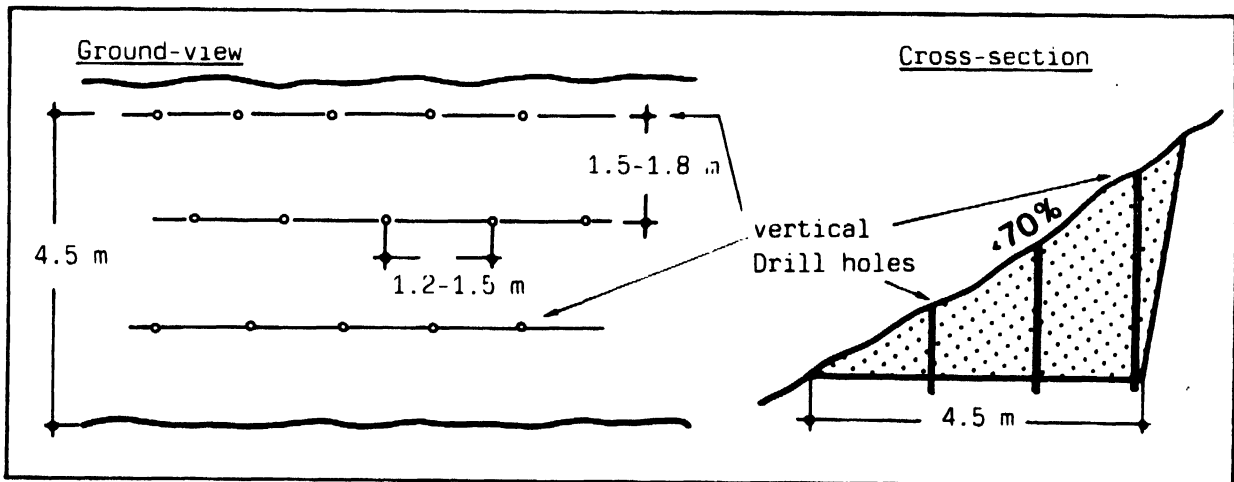


Fig. 8 MANUAL DRILLING SCHEME ON A SLOPE

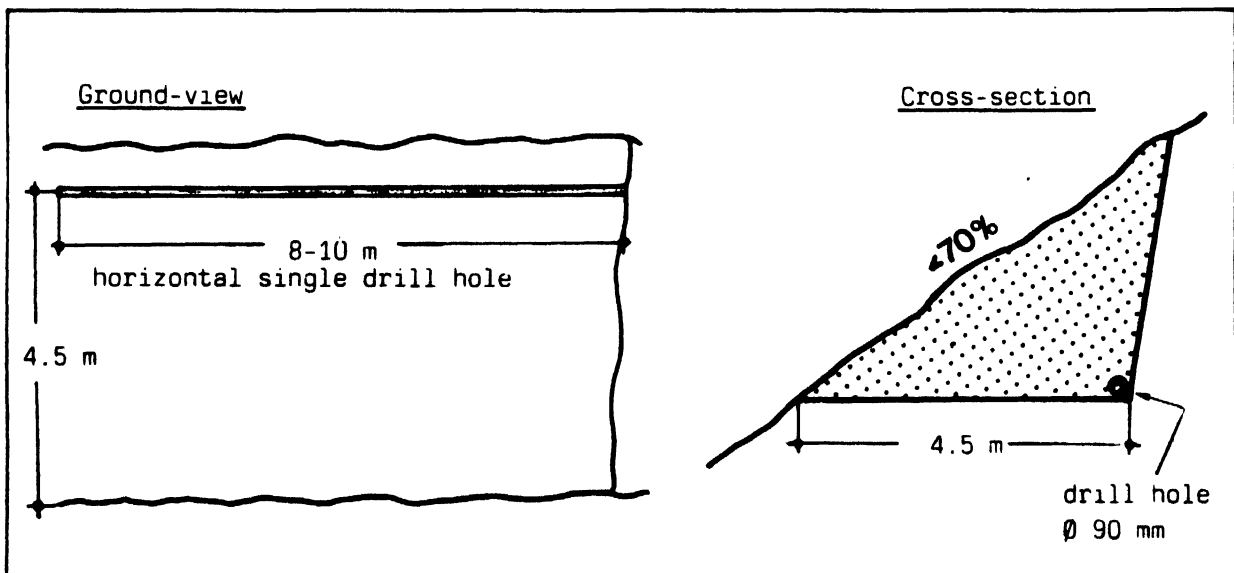


Fig. 9 MACHINE DRILL SCHEME (INTERNAL DRILL)

5. ROAD DRAINAGE AND EROSION CONTROL

Roads interfere with the natural drainage system of a watershed and increase erosion. Therefore, watercourses have to be crossed by means of appropriate structures (culverts, fords, bridges) and water has to be drained off the road by the shortest route.

5.1 Ditches and culverts

On flat ground triangular or trapeziform side-drains are excavated along both sides of the road formation (Fig. 10).

Slope roads are drained by means of an upper side-drain and cross culverts, the latter located on the road surface or underneath it (Fig. 11).

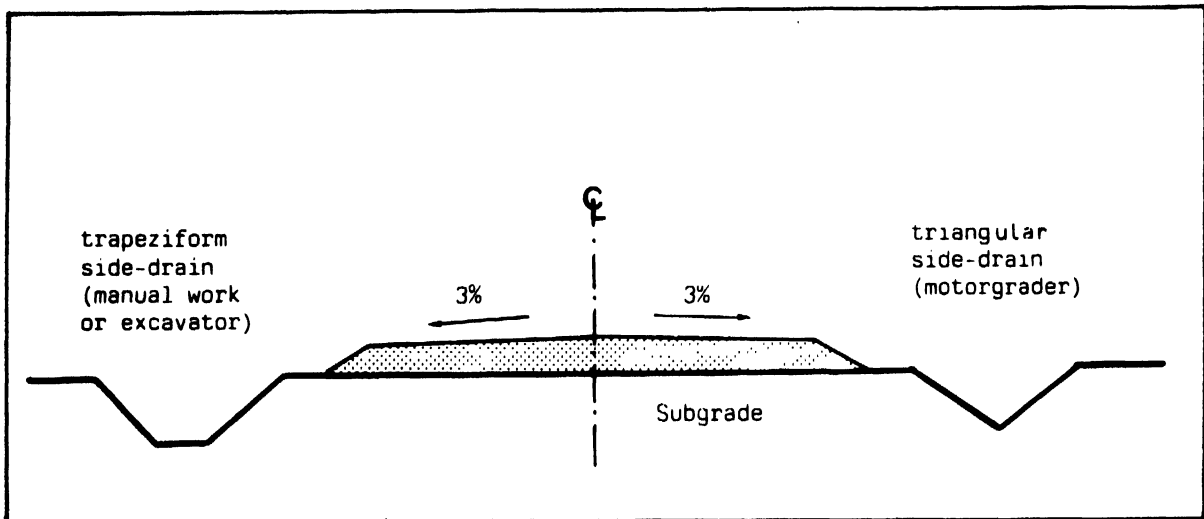


Fig. 10 ROAD DRAINAGE ON LEVEL GROUND BY MEANS OF SIDE-DRAINS

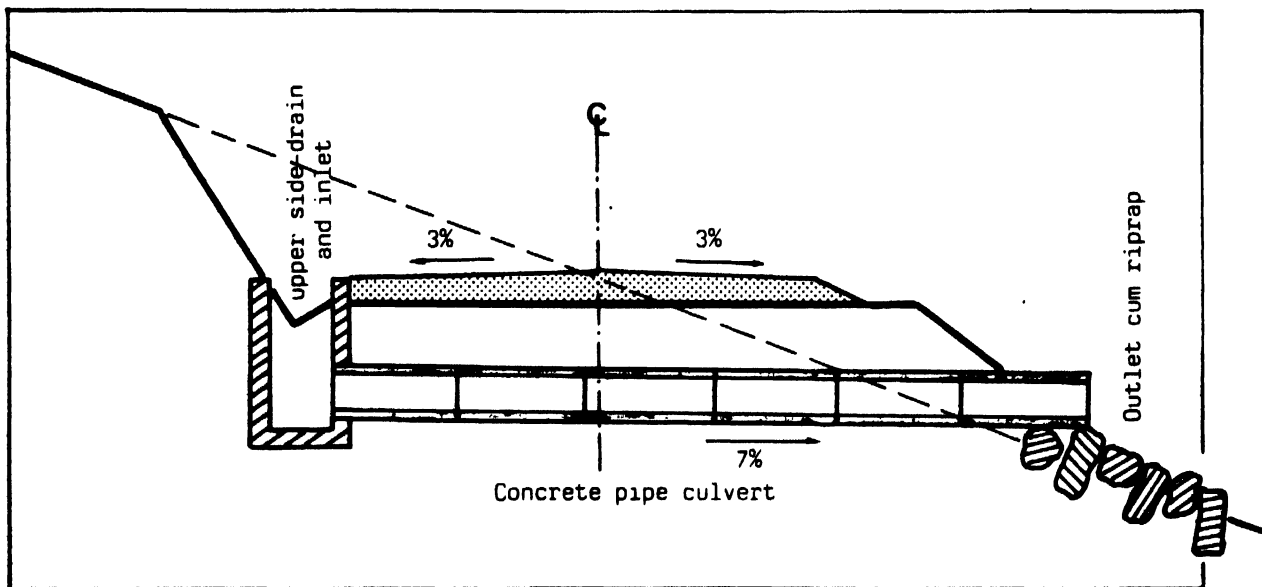


Fig. 11 ROAD DRAINAGE ON A SLOPE BY MEANS OF UPPER SIDE-DRAIN AND CULVERT

5.1.1 Open-top culverts

Road-surface culverts are a traditional type, well known in mountainous countries, which serve for both cross drainage and erosion control.

Simple cross drains protect the road subgrade against erosion during construction. These drains, reinforced by roundwood poles, suffice also for earth roads with low traffic volume (Fig. 12).

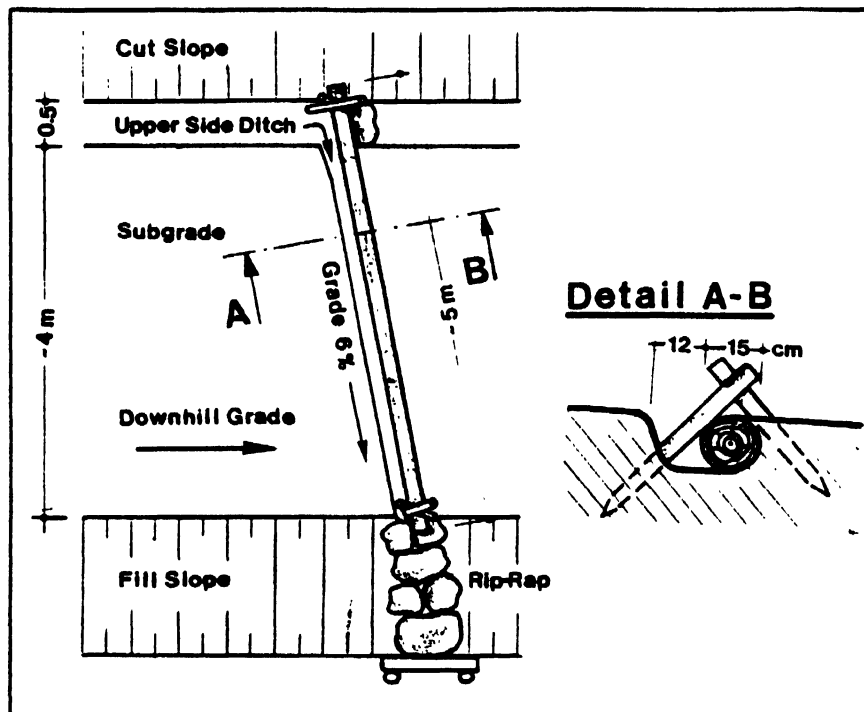


Fig. 12 SIMPLE OPEN CROSS DRAIN ON EARTH ROAD SURFACE

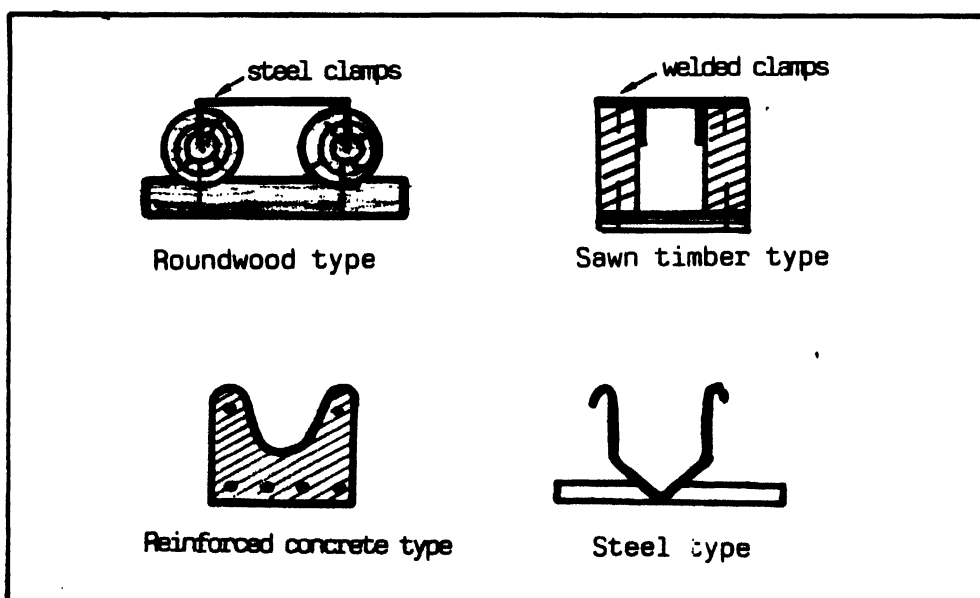


Fig. 13 DIFFERENT TYPES OF OPEN-TOP CULVERTS
(CROSS SECTIONS NOT TO SCALE)

Open-top culverts of a better standard are made of roundwood or planks. Steel and concrete culverts are prefabricated in industrialized countries (Fig. 13).

The spacing of open-top culverts depends on road grades, rainfall characteristics, side slope of terrain, and soil erodibility. For a culvert to be efficient it should have a grade of about 7 percent and regular maintenance is required. The best spacing for culverts has to be decided on the basis of local experience.

An example of average conditions is given in Table 3.

Table 3

SPACING OF OPEN-TOP CULVERTS

Road grade (%)	Spacing (m)
6	60 - 70
8	40 - 50
10	30 - 35
12	20 - 25

Despite their advantages, these surface culverts are obstacles to mechanized road maintenance by motorgraders. It is therefore recommended that road grade maximum be reduced to 9 or 10 percent and surface cross drains be replaced by underground culverts wherever mechanized road maintenance is carried out.

5.1.2 Underground culverts

Concrete pipes with diameters of 30 - 100 cm and a piece-length of 1 m, at intervals of 10 cm, are the culvert elements preferred in industrialized countries. Concrete pipes can also be locally produced in developing countries by means of rather simple formwork and installations.

Corrugated steel culverts have wider spans of up to 2.5 m, but they are costly. Culvert plates can easily be transported and mounted even on remote construction sites, but a steel culvert has to be carefully embedded in compacted, well-graded gravel.

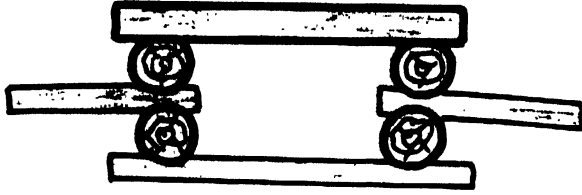
If pipes are not available, culverts can be constructed in various locally-found materials (stones, masonry, slabs, timber).

Fig. 14 shows some types of culvert.

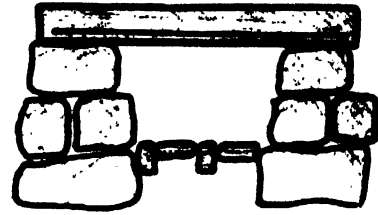
In steep terrain the location of culverts is critical to avoid erosion, because slope roads concentrate water run-off in the same way as a gutter. As far as possible, cross-drainage outlets should be located at existing small watercourses to avoid the erosion of new ravines. Culvert outlets should be protected against erosion by means of riprap or timber crib revetments.

Boulder or timber crib revetments also support culverts and protect embankments across ravines or creeks.

Culverts of local material

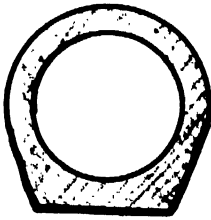


Timber crib type



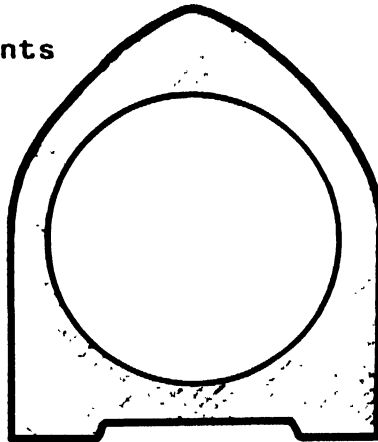
Masonry-slab type

Culverts of prefabricated elements



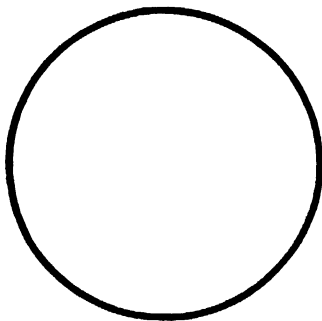
Concrete pipes

Normal type (\varnothing 30-50 cm)

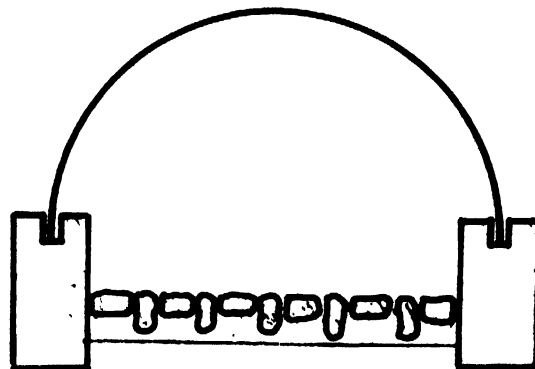


Heavy load type (\varnothing 60-100 cm)

Culverts made of corrugated steel plates



Circle profile



Half circle profile on abutments

Fig. 14 CULVERT TYPES (CROSS-SECTIONS NOT TO SCALE)

5.1.3 Erosion control

Road construction considerably increases the erosion rate, especially in watersheds with highly erodible soils and heavy rainfalls.

Besides proper planning and technical erosion control, immediate revegetation of cut and fill slopes reduces the erosion rate, which at the initiation of road construction may be excessive. Organic topsoil should be spread on cut and fill slopes to facilitate revegetation. Manual work and excavators meet this goal, bulldozers do not.

If conditions are favourable natural vegetation will soon grow on the organic top layer. Under unfavourable conditions manual or mechanized seeding of cut and fill slopes is advisable.

The stabilisation of landslides along the road depends primarily on proper drainage, because underground water is usually the trigger for them on unstable sites. Additional revetments, wattling or contour planting will stabilize these critical spots.

6. BASE CONSTRUCTION

6.1 Some aspects of soil mechanics

The subgrade's bearing capacity depends on subsoil properties classified by means of numerous criteria; for example, mineral origin, grain size and distribution, as well as water content.

The Unified Soil Classification System (USCS) is widely used to classify subsoils and base material for engineering purposes.

Table 4

TERMS AND GRAIN SIZES ACCORDING TO USCS

Symbol	Term	Grain size (mm)
G.	gravel	2.0 - 60.0
S.	sand	0.06 - 2.0
M.	silt (mud)	0.002 - 0.06
C.	clay	< 0.002
O.	organic	---
<u>Additional properties are:</u>		
.W	well graded	grain sizes well distributed
.P	poorly graded	grain sizes poorly distributed
.L	low liquid limit	low plasticity
.H	high liquid limit	high plasticity

According to this scheme, soil material can be roughly classified by field tests or more exactly by laboratory probes.

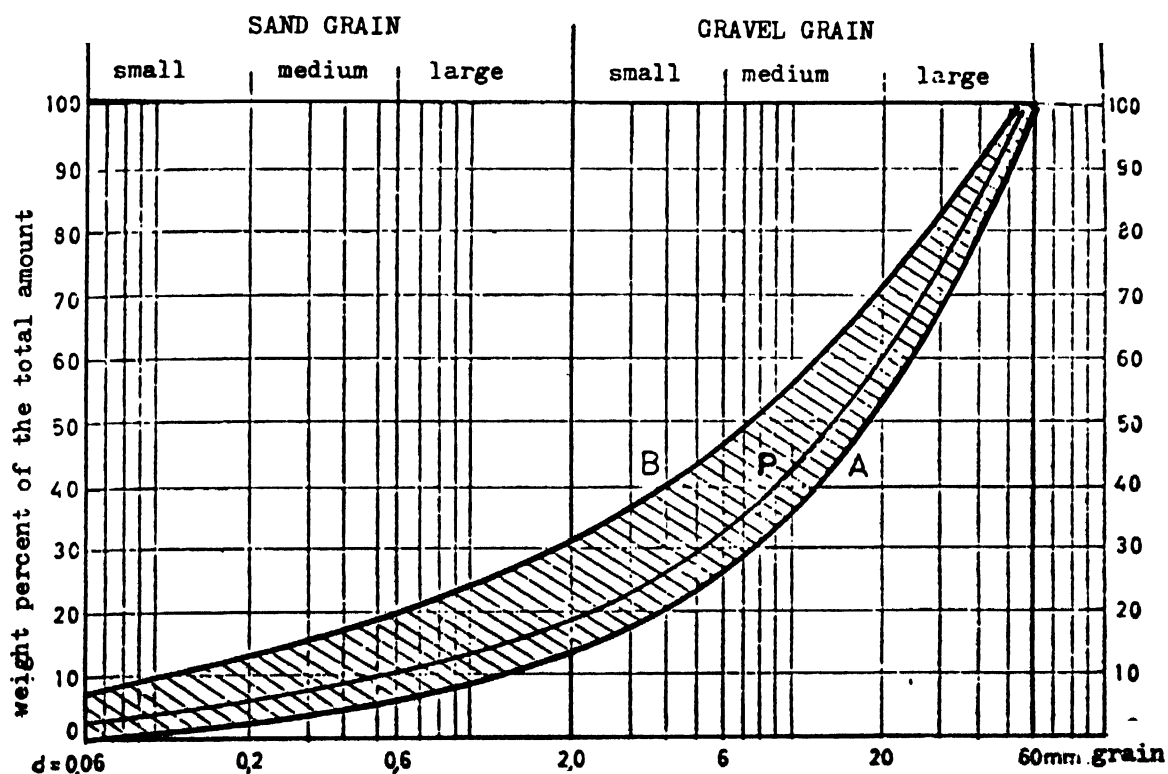
Common soil classes are, for example:

- G.W ... well graded level
- S.P ... poorly graded sand
- S.M ... silty sand
- S.C ... clayey sand.

For road engineering, coarse-grained soil material with a minimum proportion of silt and clay, e.g., G.W, G.P, S.W, S.P, yields a good subgrade quality of appropriate bearing capacity. This material is also stable in fills and embankments, but fine-grained, silty and clayey soils, e.g., M.L, C.L, are not, because their properties depend on the water content. The latter soils are water sensitive and their presence in road construction is frequently crucial.

Silty and clayey soils can, however, be improved by mechanical or chemical stabilization. In these subsoils an all-weather road must at all costs have a base.

Material suitable for base construction has to meet relatively high standards even for low-cost roads. It should be sandy gravel (G.W + S.W) with appropriate grain distribution (Fig. 15). The favourable grain distribution in this figure conforms to a parabolic curve (the "Fuller parabola"). Such material can be well compacted to a tight base layer. A compacted base layer



A, B marginal sieve curves

P quadratic parabola

CURVES OF WELL-GRADED AGGREGATE (FAO 1982)

distributes wheel loads to reduce stress on the subgrade to an amount commensurate with its bearing capacity. Stress reduction depends on base quality (material and compaction) and base thickness.

To find out the adequate base thickness is a central problem in road engineering, since the base course is the most expensive part of a road on clayey subsoils. Individual base dimensions can be determined by field methods based upon scientific research; for example, the California Bearing Ratio (CBR) method to determine subsoil quality, or, as is generally the case in forest road construction, by practical trials and experience gained on the site.

6.2 Base types and material

In contrast to public roads with different traffic characteristics, bituminous surfacing is not economic in forest road construction. Blacktopped roads are too costly and are quickly destroyed when exposed to harvesting operations.

Base types depend on the locally available material and construction methods. There are three major types (Fig. 16):

- Hand-pitched stones with surfacing (manual work)
- Dumped stones with surfacing (manual or mechanized work)
- Gravel or rubble base (macadam), (manual or mechanized work)

Well-graded natural gravel or rock aggregate is suitable for base material (grain distribution: see Fig. 15). Material of poor quality can be upgraded by adding aggregate of the required size and quantity (mechanical stabilization).



Fine aggregate surfacing (G.W.+S.W)

Base of hand-pitched stones

Hand-pitched stones (manual work)



Fine aggregate surfacing (G.W.+S.W.)

Base of dumped stones

Dumped stones (manual or mechanized work)



Fine aggregate surfacing (S.W.)

Mixed gravel (G.W.)

Mixed gravel (Macadam) (manual or mechanized work)

Fig. 16 TYPES OF BASE

Within the base layers aggregate grain sizes should decrease from the bottom to the surface. Coarse material is used for the subbase and base, fine aggregate for surfacing.

6.3 Base construction techniques

6.3.1 Initial considerations

Clayey subsoils with low bearing capacity are a major limiting factor in road construction with regard to both performance and costs. The road corridor and its vicinity should be prospected for this information as early as the road location stage, since base material should be produced as close as possible to the construction site to reduce hauling costs.

Wherever coarse material is excavated along the site, it should be reserved for base construction. In some areas gravel can be excavated from pits or rock can be blasted and crushed in quarries close to the construction site.

Hauling material over long distances is costly and damages the access roads. Proper timing (in the dry season) and organization (number of trucks and intervals) are essential for an efficient operation.

6.3.2 Labour-intensive work

In developing countries base material is frequently produced by hand. Gravel is manually excavated with picks and shovels or boulders are crushed to stones and rubble with hammers. Loading is carried out manually on to carts or small field-railway trucks for hauling.

Hand-pitched stones with a surface layer of fine aggregate is a labour-intensive base type suited to a large labour force. A gravel base (macadam) can also be manually constructed. The layers are compacted by means of a pulled roller.

As in subgrade construction, manual work can be facilitated by adequate equipment and ergonomic work techniques; for example, utilizing the force of gravity for loading and hauling material.

6.3.3 Intermediate technology

As in subgrade construction, combined manual work and machines can be an economic option for base construction. Small wheeled or tracked loaders, wheeled tractors with trailers, and stone crushers facilitate performance.

6.3.4 Mechanized construction

Hand-pitched stone techniques were applied until the early sixties, but base construction is now fully mechanized in industrialized countries because of high labour costs.

Excavators or loaders excavate the material in gravel pits; mobile crusher units are employed in quarries. Excavators or loaders load the material on to heavy-duty three-axle tipper trucks (dumpers) with a capacity of about 6 to 10 m³, which haul for distances of up to 20 km. Special off-road dumpers with capacities of up to 20 m³ are employed to haul bulk volumes on the site.

Small bulldozers or tracked loaders spread the base material on the subgrade. Grading and compacting is carried out by motorgraders and vibration rollers.

REFERENCES

- | | |
|---------------------------|--|
| Allal et al.
1977 | Manual on the planning of labour-intensive road construction,
ILO, Geneva. |
| Caterpillar Corp.
1984 | Performance handbook. |
| FAO
1982 | Logging of mountain forests, Forestry paper No. 33, Rome. |
| FAO
1982 | Basic technology in forest operations, Forestry paper No. 36,
Rome. |
| Sedlak, O.
1985 | Mountain forest roads in rural communities of Alpine Central
Europe, WFC, Mexico. |

COSTS AND PRODUCTION IN FOREST ROAD CONSTRUCTION

by

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1. INTRODUCTION

1.1 Efficiency and cost accounting

Economic activities aim at efficiency. Efficient or economic operations and projects optimize the output/input ratio or benefit/cost ratio. In different terms, economic options are an approach to achieving given objectives at the lowest cost.

The term "costs" as used in this paper refers to direct road construction costs expressed in monetary terms. The amount and the price of labour, material and equipment determine the costs assessed by means of cost accounting.

Costing procedures provide input data for cost comparisons or cost-benefit analyses. Therefore, cost accounting is a basic element of economic decisions.

There are numerous costing objectives in forest road construction:

Precalculation

- Cost estimates of alternative road locations and/or different technologies in order to determine the most economic option;
- Cost estimates of individual road projects in order to provide data for financial analyses, project decisions, and budgeting.

Accompanying (or intermediate) costing

- Cost control to check and amend precalculated values in the course of construction.

Recalculation (feedback costing)

- Cost evaluation of accomplished projects for data locally valid for future precalculations;
- Cost-price determination for tenders.

1.2 Cost elements and cost centres

The physical input factors - labour cost, capital cost for material, equipment and machines, as well as peripheral service costs (e.g., sub-contractors) - are major cost elements in forest road construction.

In addition to cost elements, costs may be allocated to cost centres as reference areas of cost origin, for example, subgrade, drainage, base course.

1.3 Cost classification

1.3.1 Direct and indirect costs

Direct costs are linked to actual performance and actual inputs, for example, labour and material.

Indirect costs or overheads do not necessarily depend on the performance level and may cover, for example, cost items such as the setting-up of camp facilities and the transportation of workers, equipment and staff.

1.3.2 Fixed and variable costs

Fixed costs are constant over a definite period. They are related to time rather than to activity; for example, setting-up and overhead costs or, to some extent, depreciation rates of machines.

Variable costs, on the other hand, depend on activity rather than on time, e.g., costs of labour and fuel.

1.3.3 Total costs and unit costs

Total costs indicate the total amount of a road project or costs of cost centres, e.g., subgrade cost, drainage cost.

Unit costs, a major topic of cost control, refer to cost per unit of time or material; for instance, cost per hour of manual work or machine hour, cost per cubic metre of material, or cost per linear metre of road.

1.4 Cost calculation schemes

Cost may be generally calculated by means of the following formula:

Amount of units x price per unit = cost.

Precalculation determines input data by means of civil engineering procedures, e.g., bill of quantity or input inventory of the road project, and figures of production.

Recalculations of accomplished projects may ascertain actual figures of production and costs. Therefore, precalculations draw on the recalculation figures of comparable operations.

Unit prices are either market prices of labour and material, e.g., dependent on contractors' tenders, or they are determined by means of cost-price calculation, e.g., for enterprise-owned machines.

Depending on objectives and inputs, the result of cost calculations can be either total costs or unit costs as illustrated by the following example:

Performance: Excavation and sidecasting of 10 000 m³ of earth by a medium-sized bulldozer, price per hour US\$ 40.

Precalculation of total cost: Average production 50 m³ per hour
Time demand: 10 000 ÷ 50 = 200 hours
Total cost: 200 h x \$ 40 = \$ 8 000

Precalculation of unit cost:

Unit time demand: $1 \div 50 = 0.02 \text{ h per m}^3$

Unit cost: $0.02 \text{ h/m}^3 \times \$ 40 = \$ 0.8 \text{ per m}^3$

Unit cost linked to total cost: $\$ 0.8/\text{m}^3 \times 10\ 000 = \$ 8\ 000$

Unit costs are the focus of cost calculations in logging and forest road construction because of their practical applicability in economic comparisons and estimates.

In order to illustrate the effects of site factors (side slope and distance) on units costs in forest road construction, Fig. 1 shows typical production charts and unit costs.

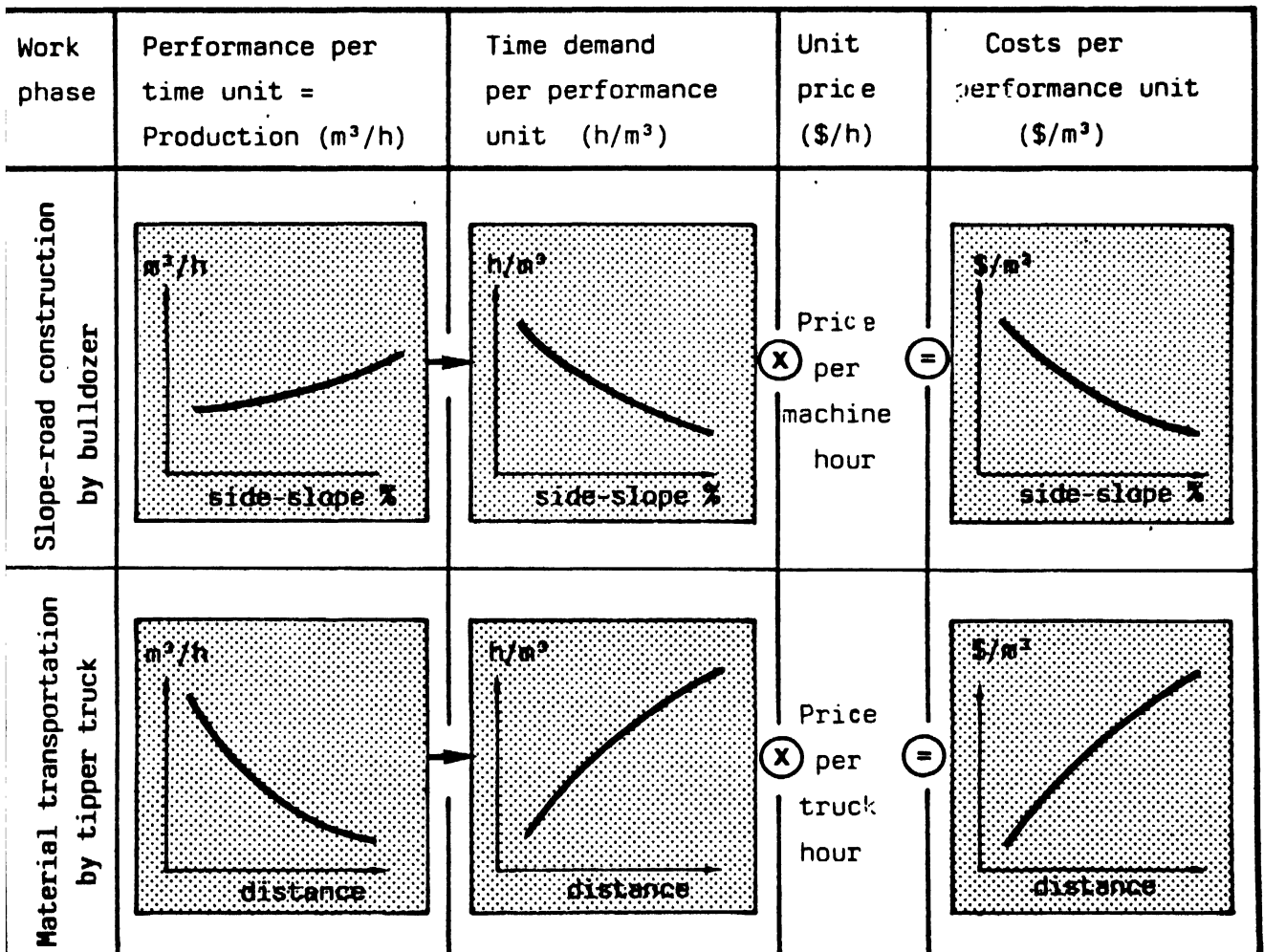


Fig. 1 TYPICAL PRODUCTION CHARTS AND UNIT COSTS
IN FOREST ROAD CONSTRUCTION (J8bst1, 1985)

1.5 Data transfer

A direct transfer of cost data between different regions is not feasible because of substantial economic and social differences. Moreover, cost data even within a country may differ widely because of different site conditions and/or technologies applied. Therefore, cost figures are comparable only on an equal basis.

2. MANUAL LABOUR VERSUS MACHINES

2.1 The global gap

Due to fast-rising labour costs, machines have replaced manual labour to a high degree in industrialized countries. Fig. 2 illustrates cost development of labour and machines in the agricultural sector of Austria, for example. Less than 10 percent of the more or less constant population depends directly on agriculture and forestry in Central Europe today. This development rests upon capital-intensive technologies and mechanization. However this situation is judged, there is no economic alternative to mechanization at present.

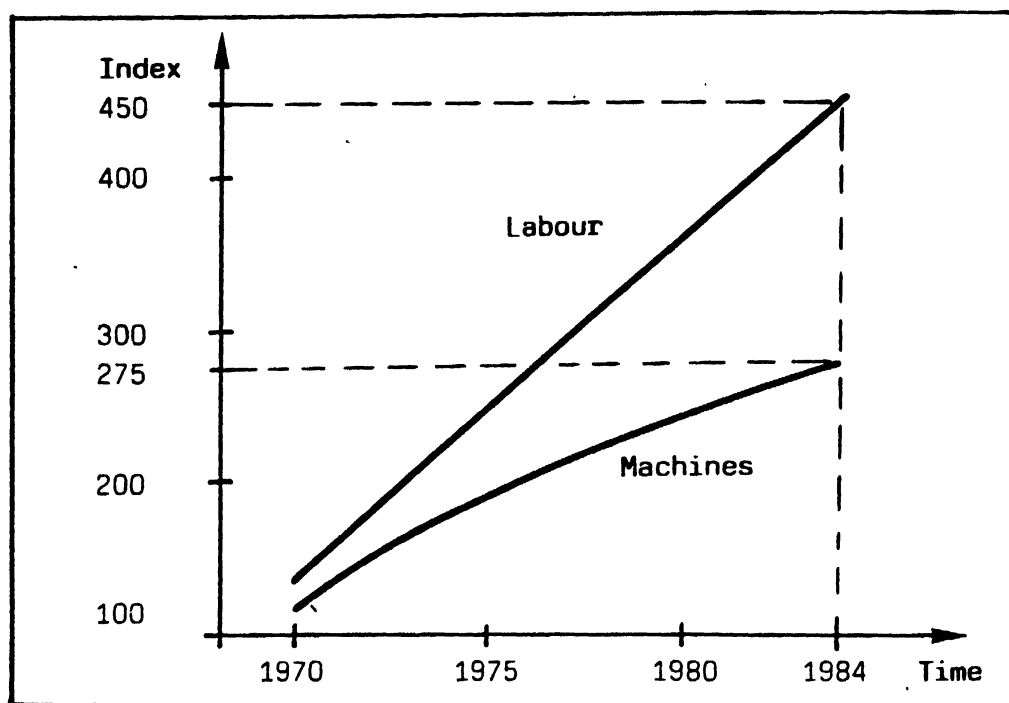


Fig. 2 COST TRENDS OF LABOUR AND MACHINES
IN THE PRIMARY ECONOMIC SECTOR OF AUSTRIA
(1966 = 100) (Landw. Paritätsspiegel)

Quite opposite trends prevail in developing countries, where economic achievements do not keep pace with population growth. On average, 70 to 90 percent of the population depends on the primary economic sector with very low wage levels. Moreover, rates of unemployment and underemployment are high, so trends of direct high-technology transfer should be scrutinized. Machines in general are extremely costly in relation to labour, and even though they may be heavily subsidized within development programmes, fully mechanized road construction cannot be socially acceptable because of local unemployment. Hence, labour-intensive techniques should be considered as feasible alternatives that must be exhaustively checked.

2.2 Manual labour

2.2.1 Wage levels and labour costs

Cost of manual labour is determined by wage levels and incidental labour costs (fringe benefits).

In industrialized countries incidental labour costs include payments for non-productive time such as breaks, travelling, sickness, holidays, leave and social expenses, e.g., family and work allowances, insurance cost.

Incidental labour costs may range from 70 to 130 percent in forest enterprises of Central Europe. Table 1 indicates average labour costs per man-hour. Normal work time is 8 hours a day or 40 hours a week.

Table 1

AVERAGE LABOUR COSTS IN CENTRAL EUROPEAN FORESTRY

Item	Unskilled labour US\$ per hour	Skilled labour US\$ per hour
Average time rate	3 - 4	5 - 6
Average incidental costs = 100 %	3 - 4	5 - 6
Total	6 - 10	10 - 12

Wage levels of unskilled workers are much lower in developing countries, ranging from less than US\$ 1 to US\$ 10 a day (Strehlke 1982). Because of deficient social security regulations, incidental costs are also very low (10 to 20 percent). Roughly estimated, average labour costs may range from US\$ 0.1 to US\$ 1.0 per man-hour.

2.2.2 Productivity

Productivity of manual work depends on labour-force characteristics, tools and equipment, site conditions and environment, as well as organization. Compared with machines, manual productivity is low and sensitive to external factors such as heat.

Table 2 shows average figures of time demand in manual forest road construction that was valid for work conditions in Central Europe some decades ago.

Table 2

TIME DEMAND IN MANUAL FOREST ROAD CONSTRUCTION (HOUR/M³)
(average figures for unskilled labour)

Subsoil class	Excavation only hours/m ³	Excavation + wheelbarrow transport 15 m, h/m ³
Earth (spades + shovels)	1 - 2	3 - 4
Hard earth (picks:shovels = 1:2)	2 - 3	4 - 5
Hard, stony earth (picks:shovels = 2:1)	4 - 5	6 - 7

In contrast to manual work in temperate climates, manual productivity in tropical countries is affected by malnutrition and heat stress.

Heat stress especially is a major limiting factor that may reduce effective work time by 30 to 85 percent depending on temperature and humidity (Axelson, 1974). Additional negative factors are inadequate equipment and organization. The average time demand for earthwork in tropical countries may therefore double the figures in Table 2. However, overall figures should not replace recalculations which are prerequisites of realistic estimates.

2.3 Machines

2.3.1 Basic considerations

Regarded as symbols of economic and technical progress, machines in fact relieve man of heavy physical work. Machine production is many times greater than manual performance; for example, one medium bulldozer may replace 200 to 400 workers in road construction.

Nevertheless, mechanization should be adapted to the economic and social framework of a country. This is not the case in reality. Technical experts, equipment manufacturers and aid-giving agencies, as well as the developing countries themselves, have promoted mechanization. "It's the machines that are privileged !" (Sandahl, 1974).

To a certain degree, however, views and opinions on mechanization have changed and cost-benefit criteria in a broad sense may increasingly influence machine acquisitions. One important piece of information that should be at hand is true machine cost.

2.3.2 Machine costs

Machine-acquisition costs are similar throughout the world because of international trade connections. Operating costs, however, may vary with different economic conditions which have to be considered by means of local input data.

There are several accounting schemes for machine costs based upon the following cost components:

- Machine owning costs:
 - Depreciation
 - Interest
 - Insurance and miscellaneous fixed charges (e.g., taxes, garage)
- Machine operating costs:
 - Fuel and lubricants
 - Repair and maintenance
- Operator costs.

Some of these cost items are discussed below in detail (FAO 1974, Caterpillar 1984):

Depreciation is the loss in value to deterioration (wear and tear, obsolescence over a certain time) during the economic lifetime of the machine. The acquisition cost of the machine less residual value at replacement should be recovered during the depreciation period, that is, its economic lifetime.

Depending on job conditions, maintenance and operators' experience, lifetimes of machines vary widely. Lifetime is considerably shorter under severe conditions in tropical countries, mainly through lack of maintenance and spare parts.

Table 3
MACHINE LIFETIMES

Equipment	Normal conditions	Severe conditions
Medium bulldozer	8 000 - 10 000 Hours or 5 years	6 000 - 8 000 hours or 4 years
Tracked loader	8 000 - 10 000 hours or 5 years	6 000 hours or 4 years
Excavators	8 000 hours or 5 years	5 000 - 6 000 hours or 4 years
Tipper trucks	10 000 - 14 000 hours or 5 years	6 000 - 8 000 hours or 4 years

Figures of on-the-job hours and lifetime in years, however, coincide only under favourable job efficiency. Practical experience indicates the following productive machine hours per year to be feasible in forest road construction depending on organization, transportation and repairs:

- 1 400 - 1 600 hours under favourable conditions
- 1 200 - 1 400 hours under average conditions
- 800 - 1 200 hours under unfavourable conditions.

These effective working hours considerably influence machine costs due to the share of fixed costs (Fig. 3).

Annual interest cost may be approximated by accounting 60 percent of the acquisition cost as average investment over the machine's lifetime.

Insurance and miscellaneous costs have to be individually calculated. If no local data are available, the annual costs may be estimated at 3 percent of the acquisition cost.

Costs of fuel, lubricants and filters are precalculated by means of manufacturer's instructions. Fuel cost is estimated by the following formula: Average hourly consumption x local unit price of fuel = hourly fuel cost.

On average, diesel-fuel prices now range from US\$ 0.3 to US\$ 0.8 per litre.

Average cost of lubricants and filters may be estimated at about US\$ 0.5 per hour of medium machines or approximately 3 to 5 percent of fuel cost.

Repair and maintenance costs include costs of spare parts, mechanic labour and workshop overheads. Annual repair costs increase with effective working time and over the machine's lifetime.

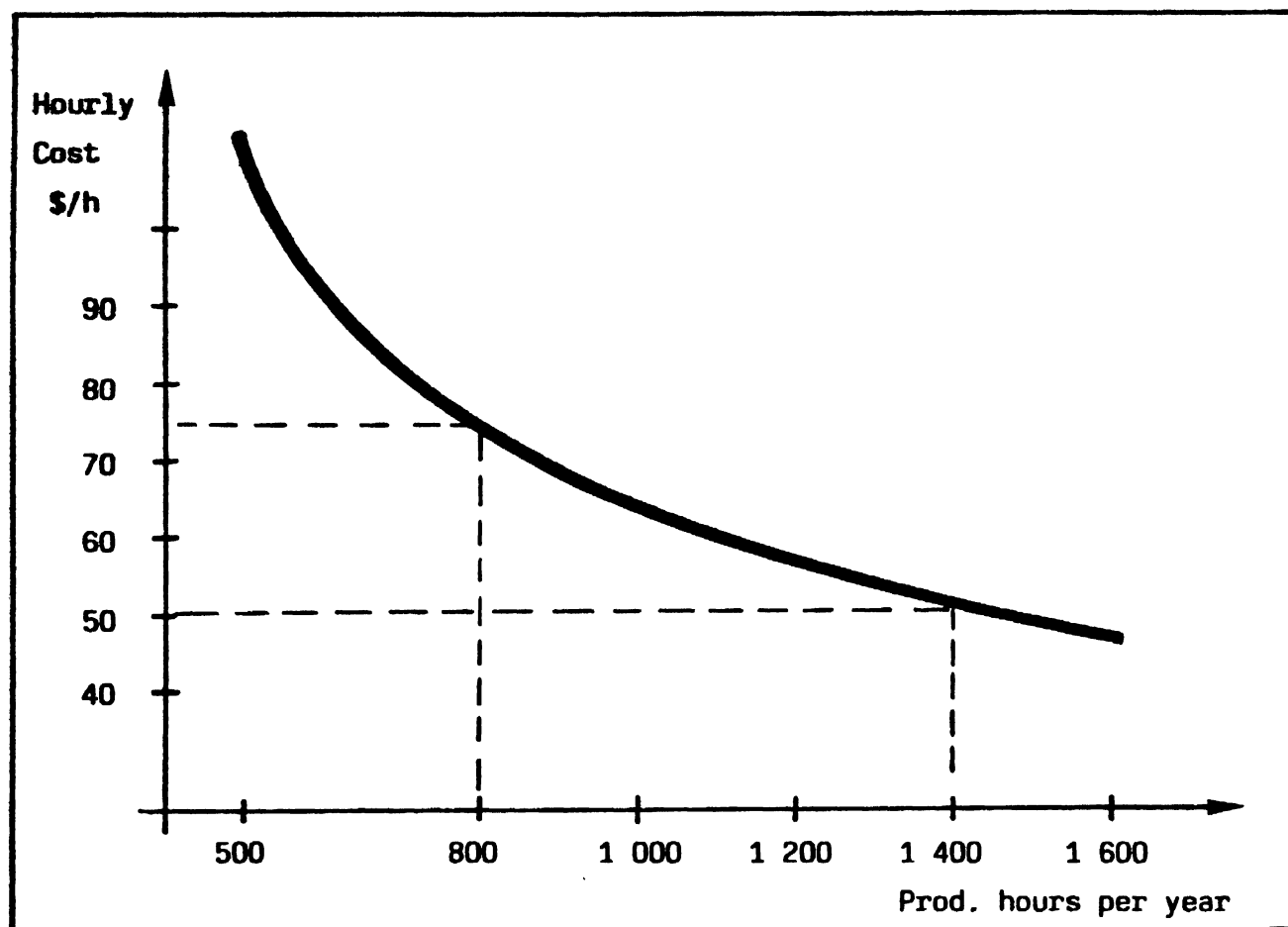


Fig. 3 PRODUCTIVE MACHINE HOURS PER YEAR AND HOURLY COSTS
OF A MEDIUM BULLDOZER (See Table 5)

In precalculations, repair costs for heavy-duty equipment may be estimated at 30 to 50 percent of the annual depreciation. Caterpillar charts indicate mean repair cost of about \$ 5 to \$ 6 per hour for medium earthmoving machines. Allowing for severe job conditions, FAO has suggested 40 percent of annual depreciation (fixed rate) plus 3 percent of the annual depreciation rate per 100 hours annually worked (variable rate). The latter estimation equals an average hourly repair amount of about \$ 8 to \$ 10.

Operator costs differ substantially between industrialized and developing countries. While annual wage costs (including social cost) may exceed \$ 20 000 in Central Europe, in developing countries operator costs are marginal compared with machine costs.

Table 4

AVERAGE DIESEL-FUEL CONSUMPTION OF CATERPILLAR MACHINES
IN LITRES PER HOUR

Bulldozer D6D	23 - 30 l/h
Excavator 225	15 - 20 l/h
Tracked loader 953	15 - 20 l/h

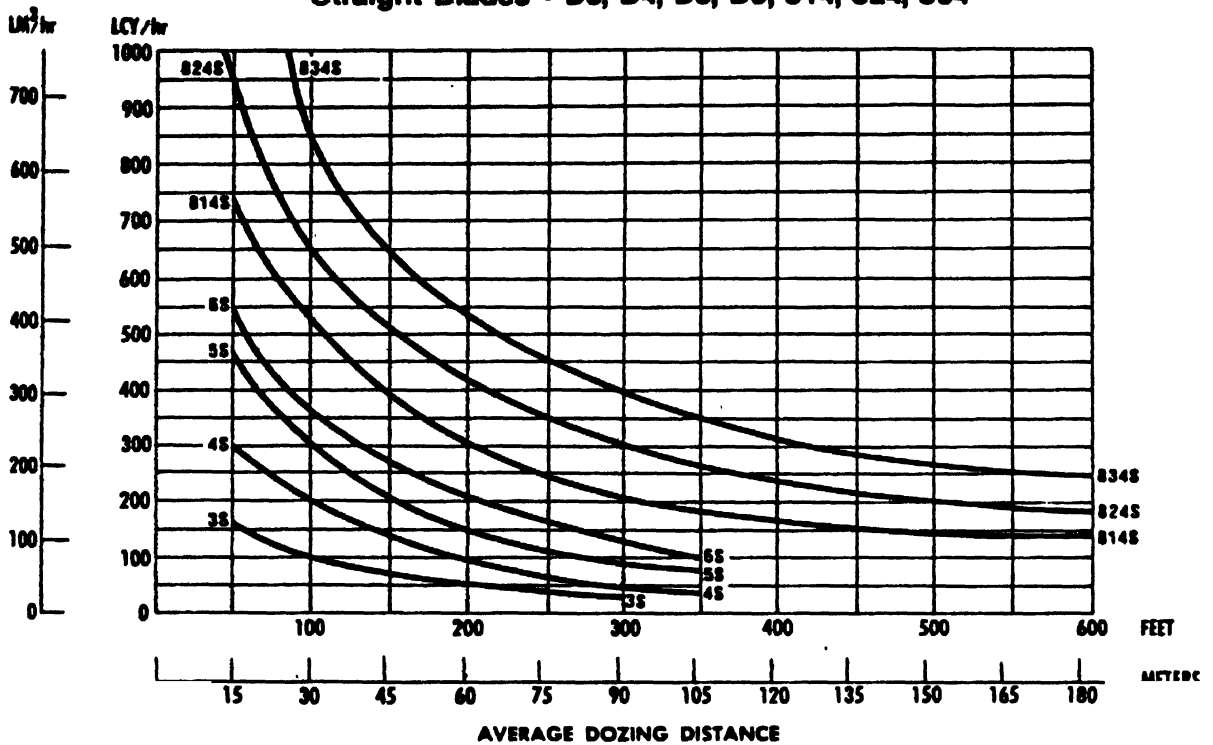
Table 5

EXAMPLE OF MACHINE COST CALCULATION (Austria 1986)

Machine: Bulldozer, Caterpillar D5H/5S, acquisition price \$ 110 000, economic lifetime: 6 years, annual operation: 1 400 hours			
Acc. No.	Cost items	Calculation	Cost in \$ per hour
Hourly owning cost (fixed cost)			
1	Depreciation, residual value 10 % of price	$\frac{110\ 000 \times 0.9}{6 \times 1\ 400} =$	11.80
2	Interest, annual rate 10 %	$\frac{110\ 000 \times 0.6 \times 0.10}{1\ 400} =$	4.70
3	Insurance and misc.	$\frac{110\ 000 \times 0.03}{1\ 400} =$	2.35
Subtotal owning cost			18.85
Hourly operating cost (variable cost)			
4	Fuel, lubricants, filters, average fuel consumption 20 l at \$0.6	fuel 20 l x 0.6 = 12 lubric.+ filters 0.5	12.5
5	Repairs	acc. to Caterpillar chart	5.0
Subtotal operating cost			17.5
6	Operator cost Annual wage cost \$ 20 000	$\frac{20\ 000}{1\ 400} =$	14.3
Total cost per machine hour			50.65

This cost-price calculation does not include risk and profit margins of an enterprise or contractor. On the other hand, market prices depend on local machine capacities and competition in free economies. Therefore, actual hourly machine prices may differ from precalculations. Due to machine overcapacities, for example, real prices of hired machines are at present slashed by about 20 percent in Austrian forest road construction.

ESTIMATED DOZING PRODUCTION Straight Blades • D3, D4, D5, D6, 814, 824, 834

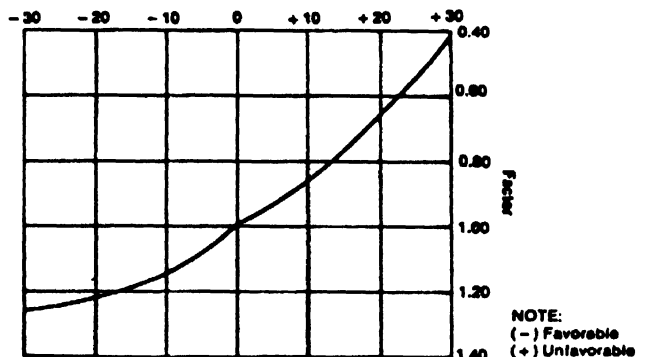


JOB CONDITION CORRECTION FACTORS

	TRACK- TYPE TRACTOR	WHEEL- TYPE TRACTOR
OPERATOR —		
Excellent	1.00	1.00
Average	0.75	0.60
Poor	0.60	0.50
MATERIAL —		
Loose stockpile	1.20	1.20
Hard to cut; frozen —		
with tilt cylinder	0.80	0.75
without tilt cylinder	0.70	—
cable controlled blade	0.60	—
Hard to drift; "dead" (dry, non-cohesive material) or very sticky material	0.80	0.80
Rock, ripped or blasted	0.60-0.80	—
SLOT DOZING	1.20	1.20
SIDE BY SIDE DOZING	1.15-1.25	1.15-1.25
VISIBILITY —		
Dust, rain, snow, fog or darkness	0.80	0.70
JOB EFFICIENCY —		
50 min/hr	0.84	0.84
40 min/hr	0.67	0.67
DIRECT DRIVE TRANSMISSION (0.1 min. fixed time)	0.80	—
BULLDOZER*		
Angling (A) blade	0.50-0.75	—
Cushioned (C) blade	0.50-0.75	0.50-0.75
D5 narrow gauge	0.80	—
Light material U-blade (coal)	1.20	1.20
GRADES — See following graph.		

* Note: Angling blades and cushion blades are not considered production dozing tools. Depending on job conditions, the A-blade and C-blade will average 50-75% of straight blade production.

% Grade vs. Dozing Factor



ESTIMATING DOZER PRODUCTION OFF-THE-JOB

Example problem:

Determine average hourly production of a D8/8S (with tilt cylinder) moving hard-packed clay an average distance of 150 feet (45 m) down a 15% grade, using a slot dozing technique.

Estimated material weight is 2650 lb/LCY (1600 kg/Lm³). Operator is average. Job efficiency is estimated at 50 min/hr.

Uncorrected Maximum Production — 680 LCY/hr (505 Lm³/h) (example only)

Applicable Correction Factors:

Hard-packed clay is "hard to cut" material .. -0.80
 Grade correction (from graph) -1.19
 Slot dozing -1.20
 Average operator -0.75
 Job efficiency (50 min/hr) -0.84
 Weight correction (2300/2650) -0.87

Fig. 4 DOZING PRODUCTION CHART (Caterpillar, 1984)

In developing countries the low cost of operators is compensated by a shorter machine lifetime due to high wear and tear, as well as poor maintenance. Total machine cost may therefore be estimated at about the same amount as in industrialized countries.

2.3.3 Machine production

Machine production depends on the type of machine, the operator's skill and site and job conditions.

Fig. 4 shows a dozing production chart for crawler tractors and wheeled dozers, and illustrates correction factors for different job conditions (Caterpillar, 1984). The grade chart indicates that dozing production is much affected by adverse grades, which the work organizers should avoid as far as possible.

Table 6

EXAMPLE OF ESTIMATING DOZER PRODUCTION OFF-THE-JOB
(Caterpillar 1984)

Machine: Caterpillar D5H/5S bulldozer	
Job description: Dozing of hard soil an average distance of 15 m, adverse grade 20 %	
Maximum production at 100 % efficiency (See chart, Fig. 4): 350 m ³ per hour	
Job conditions	Correction factors
Operator - poor	0.60
Material - hard to cut	0.80
Job efficiency - 40 min/hour	0.67
Direct drive transmission	0.80
Grade - 20 % adverse	0.65
Soil weight - 1 500 kg/m ³	0.91
Correction factor	0.152
Actual dozing production: 350 m ³ x 0.152 = 53 m ³ per hour	

Although dozing charts are not valid for road sidecasting on slopes, the figures in Table 6 show features typical of bulldozer production. The operator's skill, job efficiency and grades are major factors determining the efficiency of the operation.

2.4 Determination of alternatives

A rough estimation of time demand and costs of earthwork may illustrate significant differences between world regions:

Table 7

MANUAL LABOUR VERSUS MACHINE - A MODEL CALCULATION

<p>Job description: Excavation and sidecasting (15 m) of medium subsoil in forest road construction</p> <p>Performance: Manual excavation and loading, transport by means of wheelbarrows on planks versus medium bulldozer</p>			
Country	Performance		
	Criteria	Manual work	Machine
Tropical country	Hourly costs	\$ 0.1/h	\$ 40/h
	Production	0.15 m ³ /h	40 m ³ /h
	Time demand	7 h/m ³	0.025 h/m ³
	Cost	\$ 0.7/m ³	\$ 1/m ³
Industrial country	Hourly costs	\$ 6/h	\$ 50/h
	Production	0.25 m ³ /h	50 m ³ /h
	Time demand	4 h/m ³	0.020 h/m ³
	Cost	\$ 24/m ³	\$ 1/m ³

As cost figures clearly indicate, there are no economic alternatives to earthmoving machines in industrialized countries. Only alternative road net patterns or road locations are evaluated and compared in order to determine the best option for mechanized construction.

If manual performance comes into consideration, alternatives of location and performance may be examined in developing countries. While cost accounting of alternative routes and/or construction methods may normally be carried out by the engineering staff, considerations of economic, social and environmental effects demand interdisciplinary cooperation.

3. COST ESTIMATES OF FOREST ROADS

3.1 General remarks

Proper cost estimates depend on recalculation data of comparable projects. As far as mechanized road construction is concerned, unit costs are fairly similar. If no local information on costs is available, reference data of public works departments may be collected; but these figures should be applied with some reservation because of different road standards and work techniques.

FAO has developed a formula for estimating overall forest road cost valid for mechanized construction (Heinrich, 1985). The cost comprises right of way clearing and subgrade construction. It does not include rock blasting and gravelling.

$$C_i = 370 + 27 \times SL + 1\,050 \times ST_i + 48 \times SL \times ST_i$$

C_i ... direct cost in \$ per km (cost as at 1977, to be adjusted)

SL ... mean side-slope inclination

ST_i .. values of road standards

0 ... skid trail

1 ... secondary feeder road, width 4 - 7 m

2 ... primary feeder road, width 8 - 10 m

3 ... main road, width 10 - 12 m

Example: Secondary feeder road ... $ST_i = 1$, mean side slope ... $SL = 40\%$

$$C_i = 370 + 27 \times 40 + 1\,050 \times 1 + 48 \times 40 \times 1 = \$4\,420 \text{ per km}$$

or rounded \$4.40 per m

3.2 Cost estimates and cost centres

A road-cost estimate may consist of the following cost items or cost centres:

- Land acquisition, if any
- Setting-up and overhead costs
 - Workers' camps, workshop and storage facilities (installation, operation, dismantling), transportation of workers and equipment
- Clearing right of way
- Subgrade formation
 - Earth moving, rock blasting
- Drainage
 - Drains and culverts
- Base course
 - Gravel material (opening-up of pits or quarries, blasting, excavating, crushing), loading, transporting, unloading, spreading, grading, compacting
- Structures
 - Revetments, big culverts, bridges
- Supervision
- Unforeseen costs
- Taxes, if any.

4. CLEARING RIGHT OF WAY

The cost of logging marketable timber in the road corridor is normally allocated to harvesting cost rather than to construction cost. Only underbrush cutting and removal of tops and limbs are counted as clearing cost in the narrow sense.

5. SUBGRADE

5.1 Preblasting of stumps

It is not economic to remove deep-rooted big stumps by means of a medium-sized bulldozer. For preblasting 100 - 250 g of explosives per 10 cm of diameter is necessary. Average cost per stump may be estimated at \$ 4.

5.2 Earthmoving

5.2.1 Manual performance

As already mentioned, exclusively manual performance may be regarded today as the exception even in low-wage countries.

Manual work needs accurate assessment of earth and rock quantities. Volumes are determined by exact road survey and civil engineering procedures.

Cost of earthwork (excavation and transportation) is calculated on the basis of either total time demand or unit cost per m³. The latter is common in contractors' tenders.

5.2.2 Machines

Due to the high production capacity of earth-moving machines, neither an exact survey nor an accurate computation of volume is required.

The following methods may be used to estimate mechanized forest road construction on slopes (Sedlak, 1985):

- (a) The earth quantities are calculated by means of standard cross-sections and side-slope inclination. Volumes according to side slopes are computed in m³ per subgrade metre by means of simple cross-section drawings (Fig. 5).

Fig. 6 and Table 8 show average cut volumes of earth and rock profiles per subgrade metre (width 4 - 5 m depending on side-slope inclination).

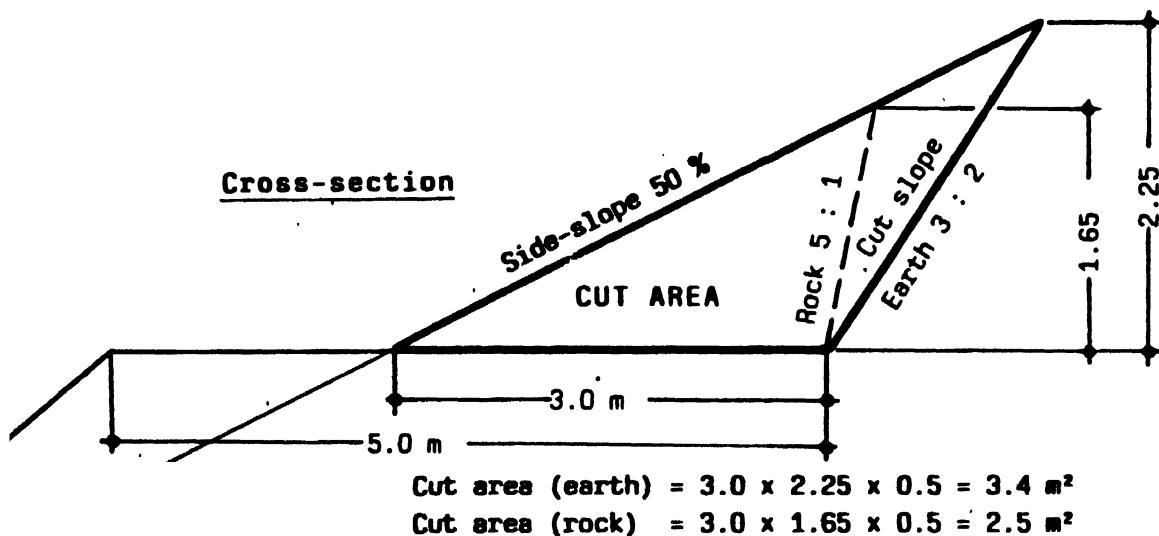


Fig. 5 EXAMPLE OF CUT-VOLUME ACCOUNTING

The total cut volume can be computed by means of the location data (side slopes and distances, estimated proportion of rock). Form sheets are recommended. Shrinkage and swell factors are not taken into account in this estimation.

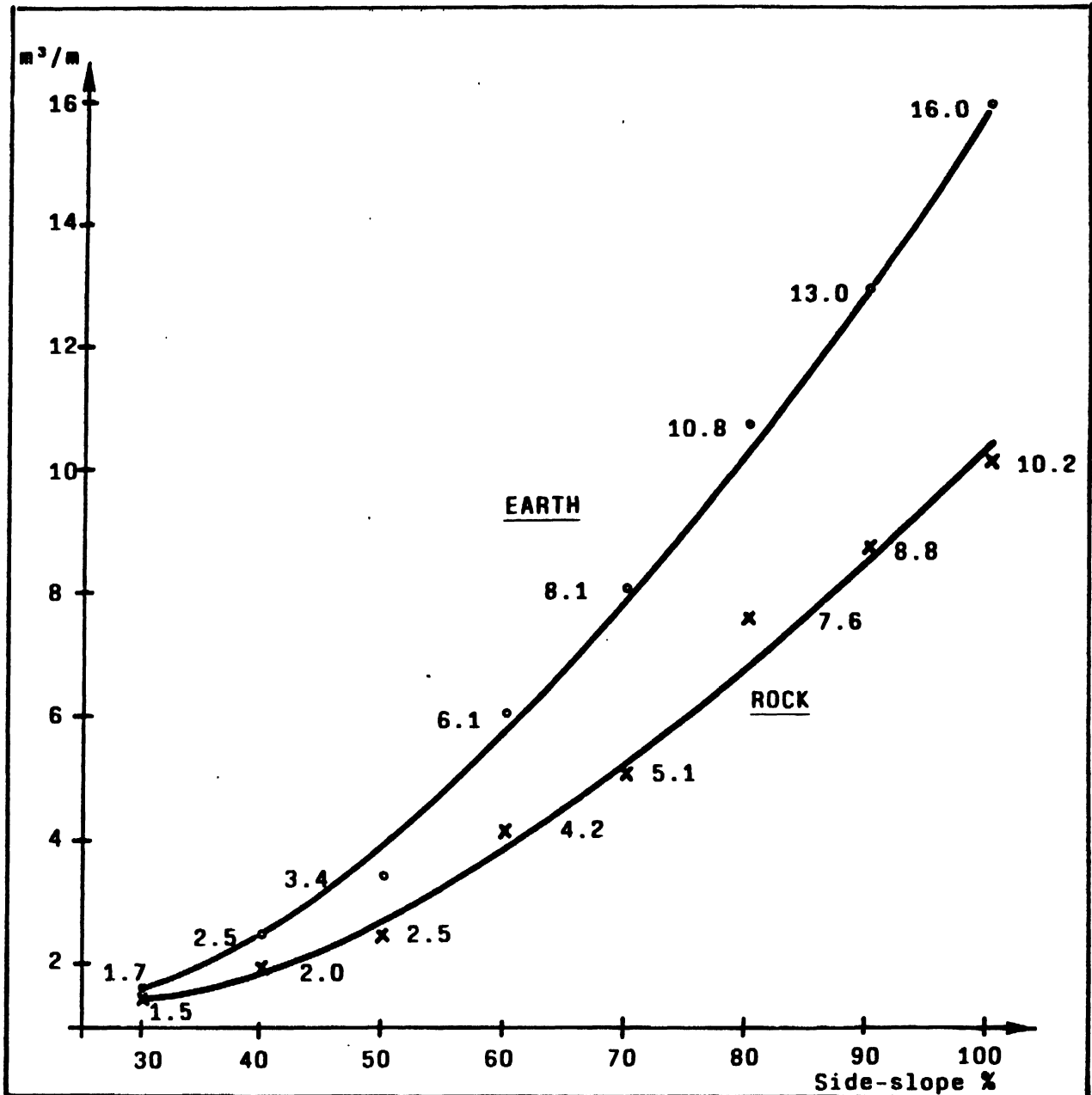


Fig. 6 CUT VOLUMES (M^3 PER LINEAR ROAD METRE)
OF FOREST ROADS ON SLOPES

The cost of earthwork is calculated as follows:

$$\text{Cost} = \text{total volume} \times \text{unit cost}$$

- (b) The average cost volume per subgrade metre is estimated according to the mean side slope.

$$\text{Total volume} = \text{mean volume per m} \times \text{total length}$$

$$\text{Cost} = \text{total volume} \times \text{unit cost}$$

- (c) Average machine cost per subgrade metre is estimated on the basis of local empirical data.

Table 8

CUT VOLUMES FOR ESTIMATING EARTHWORK IN M³
PER SUBGRADE METRE OF A SLOPE ROAD
(Sedlak, 1980)

Side slope %	Volume (m ³ per m)	
	Earth	Rock
30	1.7	1.5
40	2.5	2.0
50	3.4	2.5
60	6.1	4.2
70 <u>1/</u>	8.1	5.1
80 <u>1/</u>	10.8	7.6
90 <u>1/</u>	13.0	8.8
100 <u>1/</u>	16.0	10.2

1/ Bulldozer should be replaced by excavator. Lengthwise transportation of spoil to deposits is necessary.

Methods (b) and (c) are advisable if data from local recalculations of previous projects are available.

Machine unit costs depend on machines, subsoils and job conditions. Table 9 shows average figures of medium bulldozer production and costs of slope road construction.

Table 9

AVERAGE PRODUCTION AND EARTHWORK COSTS

Forest road: Slope feeder road, subgrade width 4-5 m Machine: Medium bulldozer (15-18 t), price \$ 40 per hour			
Accounting items	Terrain conditions		
	Easy	Medium	Difficult <u>1/</u>
Mean side slope %	30	50	70
Average volume m ³ /m	2.0	3.5	6.5
Production m ³ /h	25 - 30	30 - 40	40 - 60
Cost \$/m ³	1.3 - 1.6	1.3 - 1.0	1.0 - 0.65
Subgrade production m/h	12 - 15	9 - 12	6 - 9
Subgrade cost \$/m	2.4 - 3.0	3.0 - 4.5	4.5 - 6.5

1/ Excavator instead of bulldozer recommended.

Heavy backhoes should be employed instead of bulldozers in steep and rocky terrain with side slopes exceeding 60 percent. Backhoe production charts used for loading do not refer to job conditions in forest road construction, where empirical data indicate that the units costs in Table 9 may be enhanced by 10 to 20 percent. It must be stressed, however, that backhoes considerably reduce environmental damage and yield a better quality of performance. Therefore they are the best option in steep terrain.

On dry subsoils motorgraders may be employed for shaping cut slopes, upper side-drains and subgrade. The average production may range from 50 to 100 m per hour and cost \$ 0.3 - 0.7 per subgrade metre.

5.2.3 Rock drilling and blasting

The production of hand-held pneumatic drills depends on the hardness of the rock, the drill capacity and the operator's skill. Production figures for vertical holes may range from about 2 m/hour in granite to about 4 - 5 m/h in limestone.

About 6 m of vertical drill holes may be necessary on a steep slope with about 6 m³ of rock per subgrade metre (for a drilling scheme, see Section 4.4 of Forest Road Construction). This figure equals about 1 m of hole per m³ of rock.

Mechanized drilling by means of pneumatic or hydraulic drilling machines yields a production ranging from 20 to 70 m per hour depending on machine and rock type. Costs per metre are fairly constant under average conditions.

About 0.5 to 1 kg of explosives may be necessary to blast 1 m³ of solid rock. Efficiency in rock blasting depends on the foreman's skill and experience.

Rock blasting costs in fully mechanized operations in Central Europe may range from US\$ 3 to US\$ 5 per m³ of solid rock. Subgrade costs in rocky terrain depend on the planning of techniques and organization. Drilling capacity, for example, has to be adapted to rock volume and bulldozer or excavator capacity and vice versa.

6. DRAINAGE

6.1 Drains

Time demand for manual side-drain excavation is about 2 hours per m³. Deeper excavations for culverts show a time demand of about 4 to 5 hours per m³.

Excavators yield excellent results in trenching. Average time demand is about 0.02 to 0.05 machine hours per m³ of culvert trench, depending on the subsoil and the width of the trench.

6.2 Culverts

The commonest type of culvert is made of prefabricated concrete pipes. Table 10 shows prices (including transport cost) of such pipes in Austria as an example.

Table 10

PRICES OF PREFABRICATED CONCRETE PIPES, LENGTH 1 m (Austria 1986)

Diameter (cm)	Price US\$/m
30	7
50	17
60 HD	46
80 HD	70
100 HD	100

Mechanized pipe laying including excavation and backfilling may average US\$ 10 - 15 per culvert metre depending on the diameter of the pipe.

Cost of culvert inlet and outlet may be roughly estimated at US\$ 25 - 40.

Cost of wooden or masonry culverts have to be individually estimated.

7. BASE COURSE

7.1 Base material and quantity

Base-course cost of all-weather roads may amount to 60 percent of the total road cost on clayey subsoils. Depending on subgrade strength and vehicle loads, base thickness is normally determined by practical experience on the site and may average from 0.20 to 0.40 m of compacted material. Given a "swell-factor" of 1.5 and a base-course width of about 3.5 m, base-material demand may range from 1 to 2 m³ (loose) per subgrade metre. On wet clay the figure can exceed 3 m³ per m, whereas under favourable conditions only partial gravelling may be necessary.

In order to reduce transport costs, gravel should be produced as close as possible to the construction site.

7.2 Manual work

From the economic and the social viewpoint manual gravelling may be the best option in areas with abundant labour force and low wages.

The following data on time demand are derived from experiences in Central Europe some decades ago (Hafner 1956). In tropical countries with more unfavourable work conditions overtime should be allowed for.

7.2.1 Ballast production

Manual excavation and loading of natural gravel on wheelbarrows or field railway trucks demand about 2 - 4 h/m³.

Manual stone crushing depending on grain size: 10 - 15 h/m³
(1 m³ of solid rock equals about 2 m³ of loose ballast or 1.5 m³ of stones).

7.2.2 Transportation

Wheelbarrows on planks: distance	50 m	.....	0.8 h/m ³
	70 m	.....	1.0 h/m ³
	100 m	.....	1.3 h/m ³

Railway trucks (@ 0.75 m ³):	100 m	.....	0.6 h/m ³
	200 m	.....	0.7 h/m ³
	400 m	.....	1.1 h/m ³
	600 m	.....	1.4 h/m ³

Laying of field rails 0.2 h/m.

7.2.3 Setting and spreading

Setting of hand-pitched stones 3 - 4 h/m³
Spreading of gravel to profile 1 - 2 h/m³

7.3 Mechanized performance

If the hauling distance exceeds about 1 km, motorized transportation should be organized. Wheeled tractors with trailers (capacity 1 - 3 m³) may be a feasible means on distances up to about 3 km, especially at community forestry level.

Tipper trucks (capacity 6 - 10 m³) are the most economic vehicles over longer distances. While ballast material may be manually produced in advance, mechanized loading should be organized for job efficiency.

The following figures may illustrate average costs of fully mechanized gravelling in Austria:

Price of natural gravel depending on pit and quality	\$ 0.5 - 3/m ³
Stone crushing in mobile units	\$ 3 - 4/m ³
Loading (excavator, tracked loader)	\$ 0.6 - 0.7/m ³
Transportation (tipper truck)	\$ 1.5/m ³ + \$ 0.5 per km and m ³
Spreading (small loader)	\$ 0.5/m ³
Grading (motorgrader)	\$ 0.3/road m
Compacting (vibro roller)	\$ 0.4/road m

8. MISCELLANEOUS COSTS

8.1 Structures

Revetments, big culverts and bridges should be individually calculated.

8.2 Supervision

Overhead cost of supervision is normally accounted at 5 percent of total cost.

8.3 Unforeseen costs

To cover these, 10 percent of the total cost is allowed.

8.4 Taxes

Sales tax amounts to 20 percent in Austria, for example, and should be separately indicated in the cost estimate. So far, however, sales tax is not a cost factor in an enterprise.

REFERENCES

- Axelson, O. Heat stress in forest work, in "Employment in forestry", FAO, 1974 Rome.
- Caterpillar Corp. Performance handbook, ed. 15, Peoria. 1984
- FAO 1974 Logging and log transport in tropical high forests, Forestry paper No. 18, Rome.
- Hafner, F. Forstlicher Strassen- und Wegebau, Vienna. 1956
- Heinrich, R. Forest road-net planning and wood harvesting, in "Logging and transport in steep terrain", FAO Forestry Paper No. 14, Rev.1, Rome.
- Jöbstl, H. Cost calculation in logging, in "Logging and transport in steep terrain", FAO Forestry paper No. 14, Rev. 1, Rome.
- Sandahl, L. Employment, mechanization and problems of forest workers, in "Employment in Forestry", FAO, Rome. 1974
- Sedlak, O. Forest Roads in Bhutan, part I, FAO, Rome. 1980
- Sedlak, O. Forest road planning, location and construction techniques in steep terrain, in "Logging and transport in steep terrain", FAO Forestry paper No. 14, Rev. 1, Rome. 1985
- Strehlke, B. Forestry transport and operation problems in developing countries, ECE/FAO/ILO/IUFRO - report, Sandefjord, Norway. 1982

MAINTENANCE OF FOREST ROADS

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1. INTRODUCTION

1.1 Useful life

Hauling roads, by contrast with machines, constitute long-term investments. While the depreciation periods of gravel roads may vary from 15 to 30 years, their useful lifetime normally is much longer than tax write-off periods. With regular maintenance, truck roads may indeed be regarded as permanent investments in sustained-yield forestry.

Fig. 1 shows maintenance and reconstruction cycles of gravel roads.

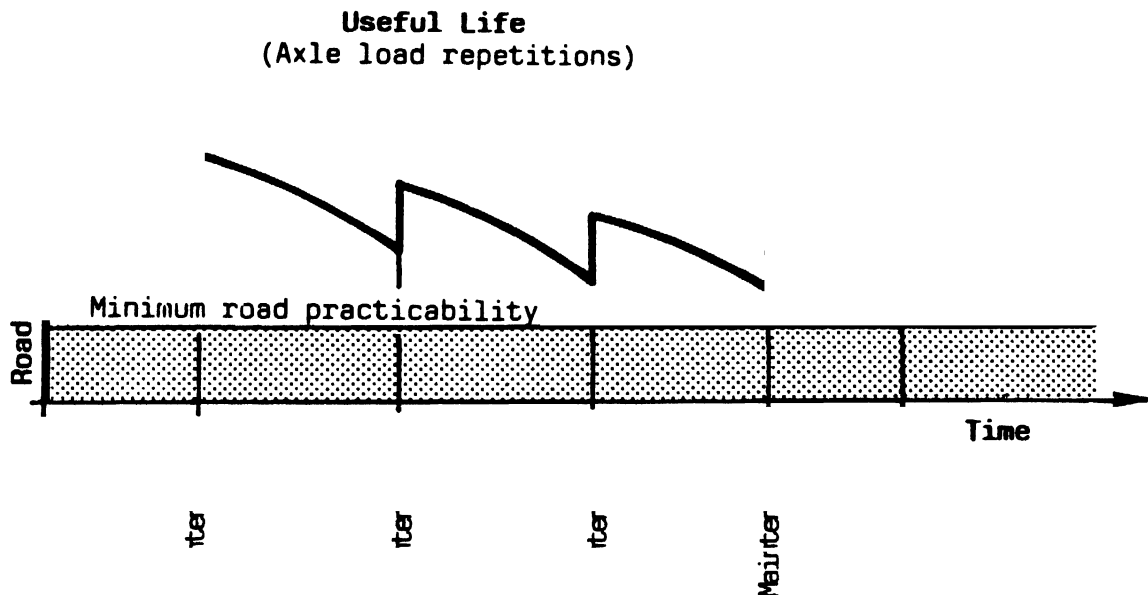


Fig. 1 ROAD MAINTENANCE AND USEFUL LIFE OF FOREST ROADS
(scheme according to Burlet, 1980)

1.2 Road standard and maintenance

To a great extent, costs of road construction and maintenance are inversely related. As a rule, the higher the road standard, the lower the maintenance costs.

As machine users have to balance machine cost and productivity, so do road engineers have to consider the trade-off between construction cost, maintenance cost, and traffic service. Fig. 2 shows an overall chart of this relation.

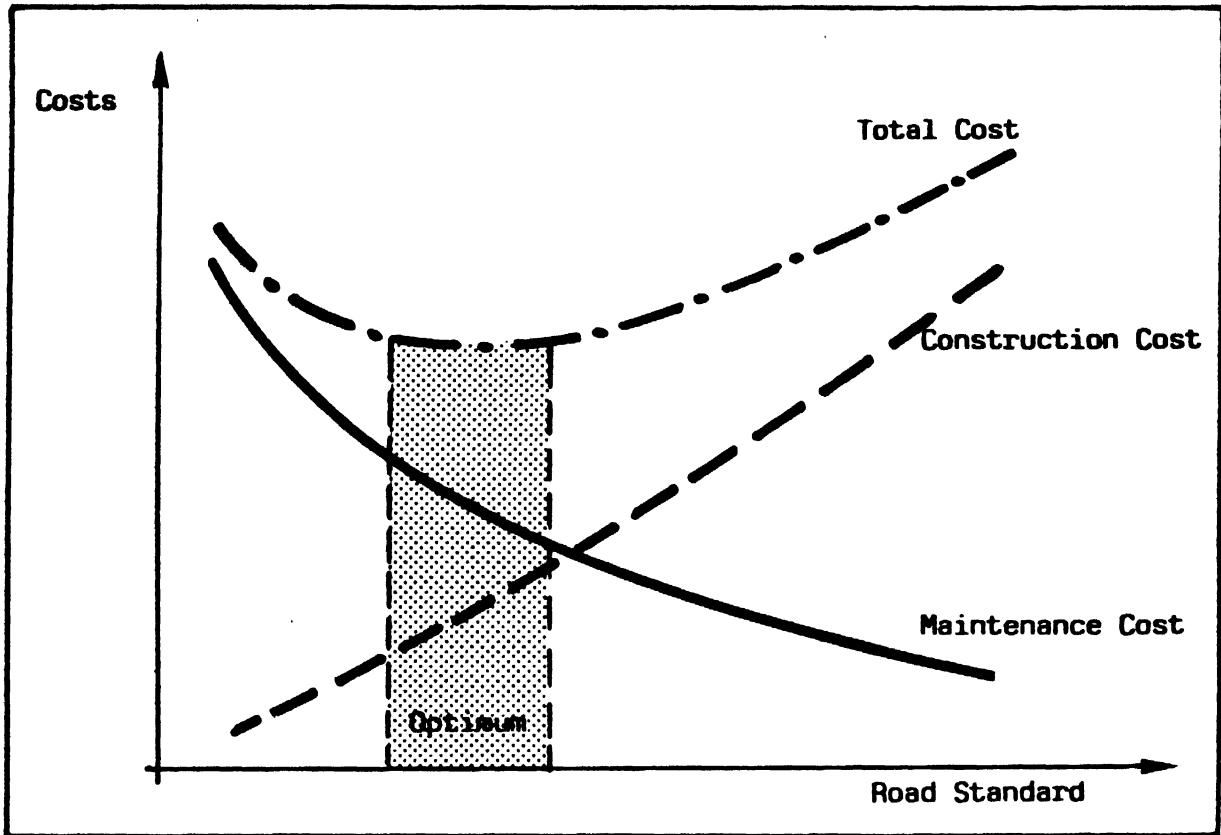


Fig. 2 OPTIMUM ROAD STANDARD

The technical range of pavement structures is rather restricted in forest engineering, because forest roads differ from public roads as regards their functions and economic considerations. Excepting major access roads with high traffic volume, costly pavements such as bituminous surfacing or concrete base courses are not economically applicable to normal forest roads. Road standards may therefore range only from fair-weather earth roads to all-weather gravel roads, which can be maintained at low cost provided they are well drained and not too steep.

1.3 Impacts on forest roads

Environment, traffic and skidding operations have an impact on the useful life period of a forest road. Frequently these effects interact; for example, traffic loads during the rainy season. In general, road maintenance is more difficult and costly in a humid climate with heavy rainfalls than in temperate or arid zones.

2. IMPACT OF THE ENVIRONMENT

2.1 Rain and humidity

Water affects the road surface, the base course, and the subgrade. Moreover, cut and fill slopes and drains are eroded. Moderate grades and good drainage are prerequisite to economic maintenance.

2.1.1 Surface erosion

Water erosion of the road surface depends on rainfall intensity, road grades and side slopes, as well as on subsoil and surface material.

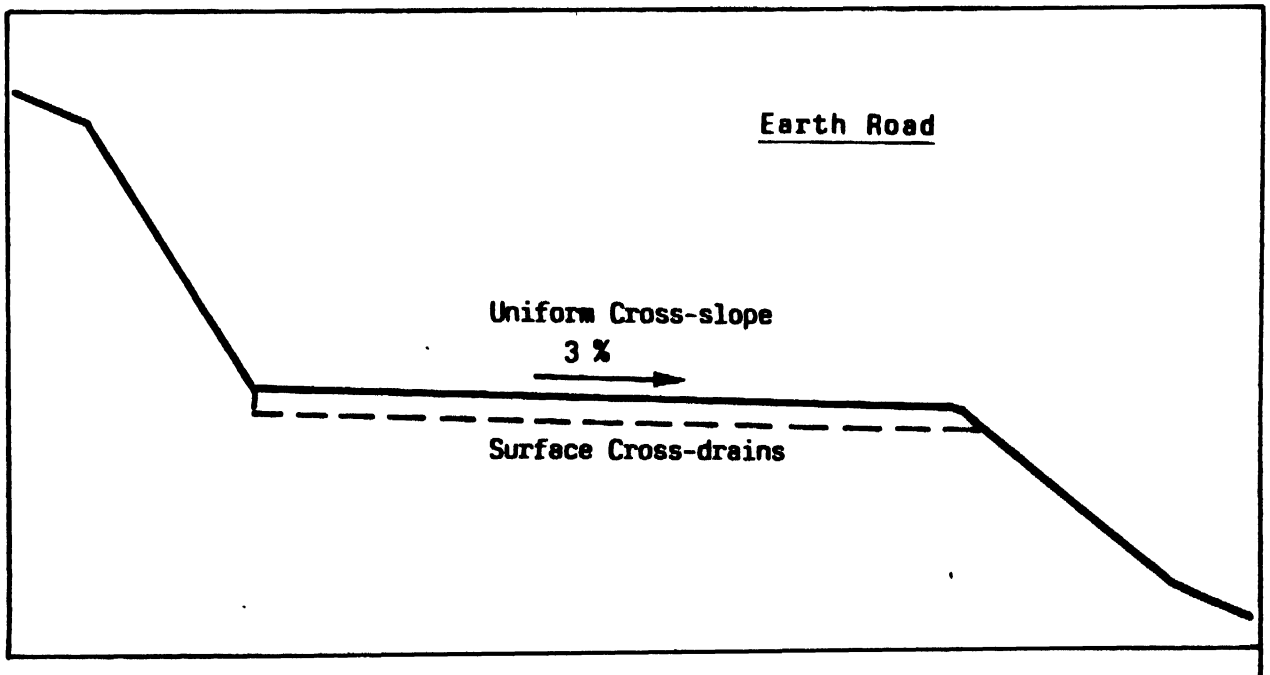
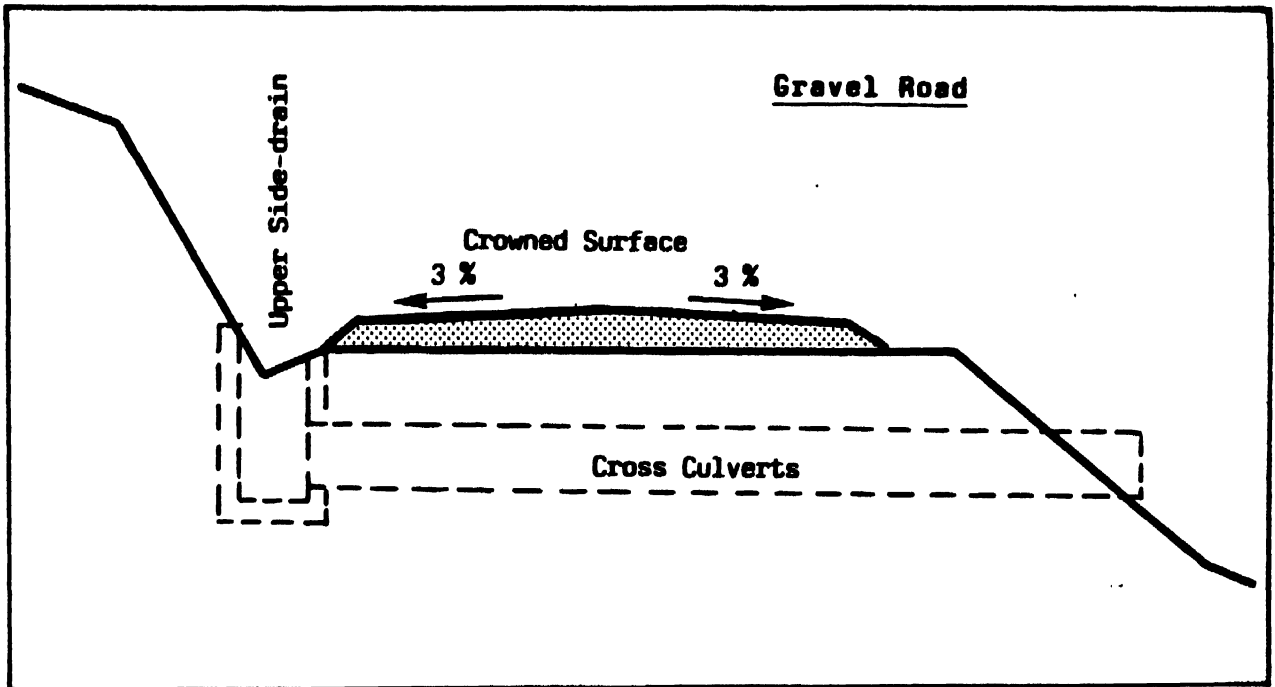


Fig. 3 DRAINAGE PATTERNS

In order to ensure economic maintenance, the grades of gravel roads should as far as feasible be limited to a maximum of about 9 percent since surface erosion exponentially increases beyond 7 percent.

On the other hand, a minimum road grade of about 3 percent is necessary to prevent water from ponding on the surface. Additional surface crowning with cross-slopes of about 3 percent facilitates surface drainage of gravel roads. The steeper the road grade, however, the less valuable the draining effect of the cross-slope.

Cross drainage on earth roads may be facilitated by a uniform cross-slope (superelevation) and cross drains such as open-top culverts, instead of crowning. Fig. 3 shows typical drainage patterns.

Lengthwise gully erosion in grooves along steep grades above 9 percent and potholes on level road sections are patterns typical of water erosion in interaction with traffic wear and tear (Fig. 4).

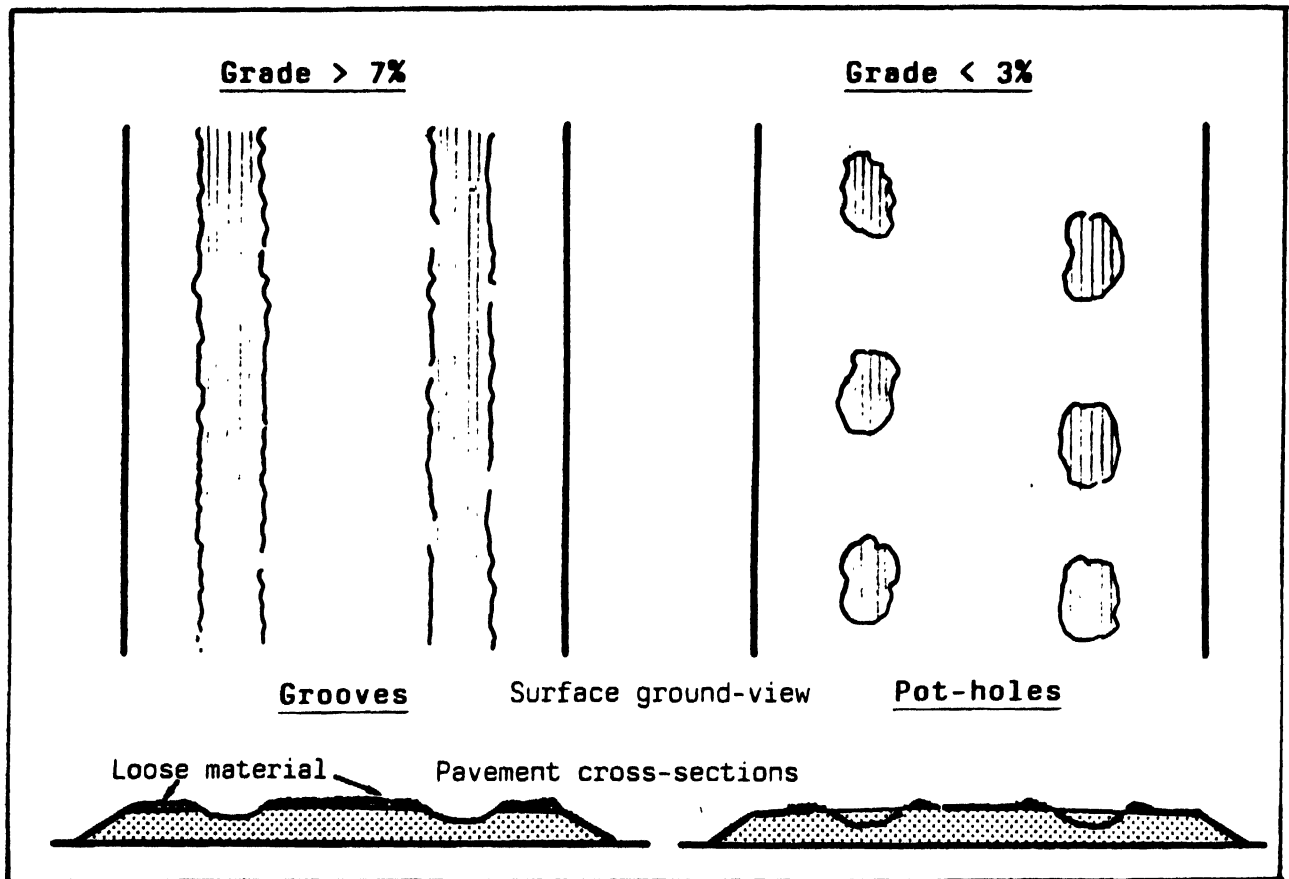


Fig. 4 WEAR AND TEAR PATTERNS ON GRAVEL ROADS

The quality of the surface material is an important factor in maintenance cost. The particles of surface gravel sealing the base course have to be well graded in order to increase the shearing strength of the road surface against erosion and the impact of traffic.

Water erosion also affects cut and fill slopes, which should be shaped to moderate grades during the construction stage. Early revegetation by rounding the upper edge of the cut slope, spreading organic topsoil, and seeding may reduce erosion and siltation.

2.1.2 Subgrade humidity

The soil strength of loamy and clayey subgrades depends substantially on the water content. Heavy axle loads may under unfavourable weather conditions cause permanent deformations of the subgrade and pavement. The drainage system, therefore, has to be well maintained and axle loads should be reduced in the rainy season to prevent major damage.

2.2 Drought

The cohesiveness of a surface course depends on the proportion of fine-grained material and its water content. If too much water evaporates in dry periods, the shearing strength is reduced and traffic may remove the finest grains in the form of dust. The road surface becomes meagre and increasingly loose.

Trials to maintain gravel roads in arid zones at low cost by applying "road oils" or calcium chloride (CaCl_2) on the surface have been fairly successful.

2.3 Temperature

The rate of evaporation is proportional to the temperature. Subgrade evaporation and restoration of its bearing capacity after rainfalls may be quicker in tropical countries than in temperate zones.

On the other hand, high temperature increases the flexibility of bituminous surface layers of access roads and may reduce their strength. Therefore, temperature is a factor influencing road maintenance and traffic service, especially in tropical countries.

3. TRAFFIC IMPACT

In addition to environmental impact, it is mainly traffic flow that determines the useful life of road pavements. While distributing and transmitting traffic loads to the subgrade, the gravel layers of a pavement are gradually worn out by wheel pressure and shearing stress.

Axle loads, traffic volume and vehicle speeds are the major factors of wear and tear.

3.1 Axle loads and traffic volume

The traffic on forest roads is characterized by low volume but high axle loads. Pavement wear and tear increases exponentially with increasing axle loads.

The AASHO 1/ test, performed in the USA from 1956 to 1961, indicated the following equivalent axle-load factors (Table 1):

1/ American Association of State Highway Officials.

Table 1

EQUIVALENT AXLE-LOAD FACTORS ACCORDING TO AASHO TEST
(Burlet, 1990)

Vehicle	Axle loads (t)	Equivalent factors	
		Single axle	Twin axle
Motor-car	0.9	0.0002	-
6-t truck	4.0	0.04	-
Norm axle (AASHO reference)	8.2	1.00	-
16-t truck	10.0	2.5	0.15
20-t truck	14.0	11.8	0.68
25-t truck	16.0	21.9	1.24
30-t truck	20.0	62	3.43

The results of this test are striking. For example, one 20-t truck with a single axle load of 14 tons may cause a pavement stress equivalent to that of about 12 trucks with an 8.2-t axle load. One 16-t truck with single axles, however, is equivalent to two 25-t trucks with rear twin axles. The results prove the economic necessity of rear twin axles for heavy trucks.

Light vehicles may be disregarded as far as impact on the base course is concerned. For example, 5 000 motor-car repetitions are equivalent to one norm-axle passage of 8.2 t.

All-weather forest roads are on average exposed to a traffic volume of about 20 000 to 40 000 norm-axle (8.2-t) repetitions over an economic lifetime of about 30 to 40 years (Dietz et al. 1984). The AASHO graph (Fig. 5) shows an approach to pavement design depending on subgrade strength.

The total transport cost (road cost + hauling cost) should be kept in mind. Reducing transportation cost by increasing payloads may result in excessive costs for road maintenance and reconstruction.

The following traffic regulations are advisable in order to increase the useful life of a pavement, and to reduce maintenance cost:

- The total weight of twin-axle trucks should be limited to a maximum of 25 tons;
- Trucks with trailers should be used in hauling instead of increasing the payloads of single trucks;
- Axle loads and traffic volume should be reduced in rainy periods.

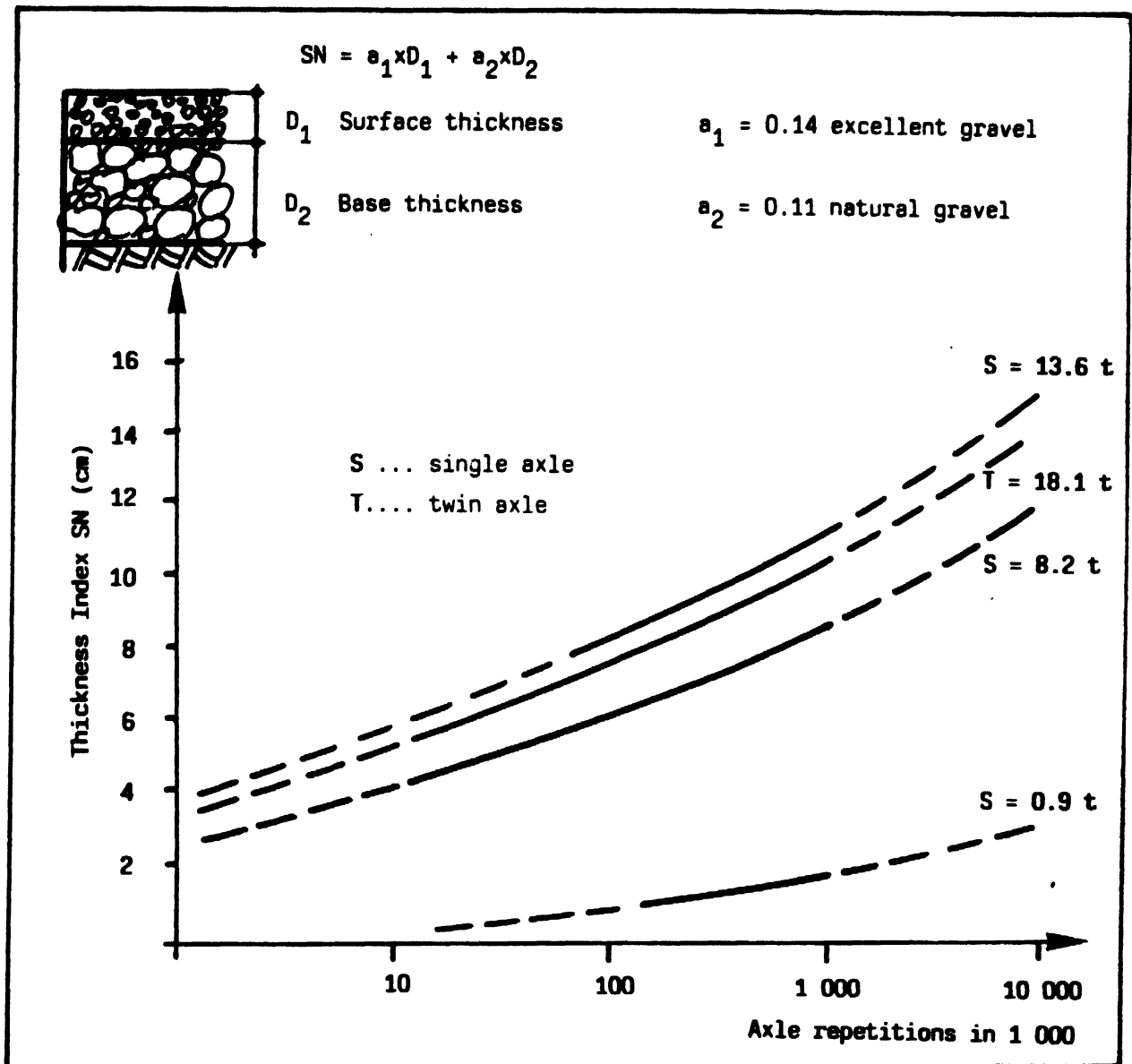


Fig. 5 AASHO CURVES (according to Hirt, 1974)

3.2 Vehicle speed

Narrow curves and rather steep grades allow only low speeds on forest roads; however, light motor-cars driven at upper speed limits may quickly damage the gravel surface by dynamic impact. The fast-turning wheels loosen and hurl off gravel particles in widening grooves. Fig. 4 shows the typical groove pattern caused by light traffic and erosion. To lessen surface wear and tear, car speeds should be slowed down and they should not be driven in surface grooves.

Big trucks wheels at low speeds have more or less roller effects on a gravel surface provided the entire pavement is stable.

4. IMPACT OF SKIDDING OPERATIONS

Road damage by machines is inevitable in logging operations but it can and should be limited by proper work organization. In contrast to a bituminous surface course a gravel road can be easily repaired.

Forest roads may be work sites for skidding and yarding, as well as for processing and decking. If the latter is carried out alongside the road, the logs should be supported by cross poles in order to keep the upper side-drain free. Heavy erosion may occur during rainstorms if the drainage system of the road is blocked by timber and harvesting residues.

The road site should be cleaned up and road-profile damage repaired after logging operations are accomplished. These repairs may range from minor maintenance to local reconstruction. Drains and culverts should be cleared of branches and twigs to allow water to run off.

5. MAINTENANCE AND RECONSTRUCTION

Regular road maintenance consists of the following elements:

- Control of road practicability and traffic impact
- Damage prevention
- Repairs.

Reconstruction is normally a major repair of worn-out pavements. As Fig. 1 illustrates, maintenance and reconstruction are carried out at more or less regular intervals in order to provide sustained practicability over the road's useful lifetime.

At present, the annual maintenance cost of gravel roads in Austria may be estimated at US\$ 300 - 600 per kilometre.

Road maintenance must be well organized. A service unit should be established for each forest district, with personnel and equipment depending on the road network and local conditions.

5.1 Road control

Regular control of the surface course and the drainage system is necessary to prevent major damage, for example, during heavy rainstorms. The logging operations along the road, as well as hauling payloads and vehicle speeds, should be controlled in order to limit wear and tear.

5.2 Damage prevention

As stressed above, short-term clearing of the drainage system is necessary to guarantee water runoff and to prevent erosion. Culverts especially are critical installations which have to be cleared continually of silt, debris, leaves and twigs. Culverts in ravines should be protected by upper rake structures in order to keep the water intakes free.

Service personnel have to be at work during rainstorms to control water runoff and to prevent major damage before it begins.

Continual minor repairs of potholes and grooves that are starting to appear may extend the intervals in regular maintenance.

5.3 Repairs

5.3.1 Labour-intensive work

Manual work is appropriate to culvert clearing and minor repairs even in countries with high wage levels.

If the surface course is also to be manually maintained, small deposits of fine gravel alongside the road should be made at distances of about 100 m to facilitate work carried out with shovels and wheelbarrows.

Simple grader devices and rollers pulled by animals or farm tractors may be used to get a smooth surface. The well-shaped surface course should be protected by a thin layer of loose, fine gravel. This fine material may be spread by towing brooms made locally of branches and twigs.

Continual control and manual maintenance need one worker for about 5 to 8 km of road, provided the small gravel deposits mentioned above are available along the road.

5.3.2 Mechanized performance

The motorgrader is the machine most preferred to maintain gravel roads in industrialized countries. Its accurate performance and high production are unmatched. Maintenance graders should have an operating weight not exceeding 12 tons.

The motorgrader scarifies and reshapes worn-out road surfaces. Loose gravel may be mixed with supplementary material transported to the site. The maximum grain size of well-graded surface gravel should not exceed 40 mm. Fig. 6 illustrates the work process.

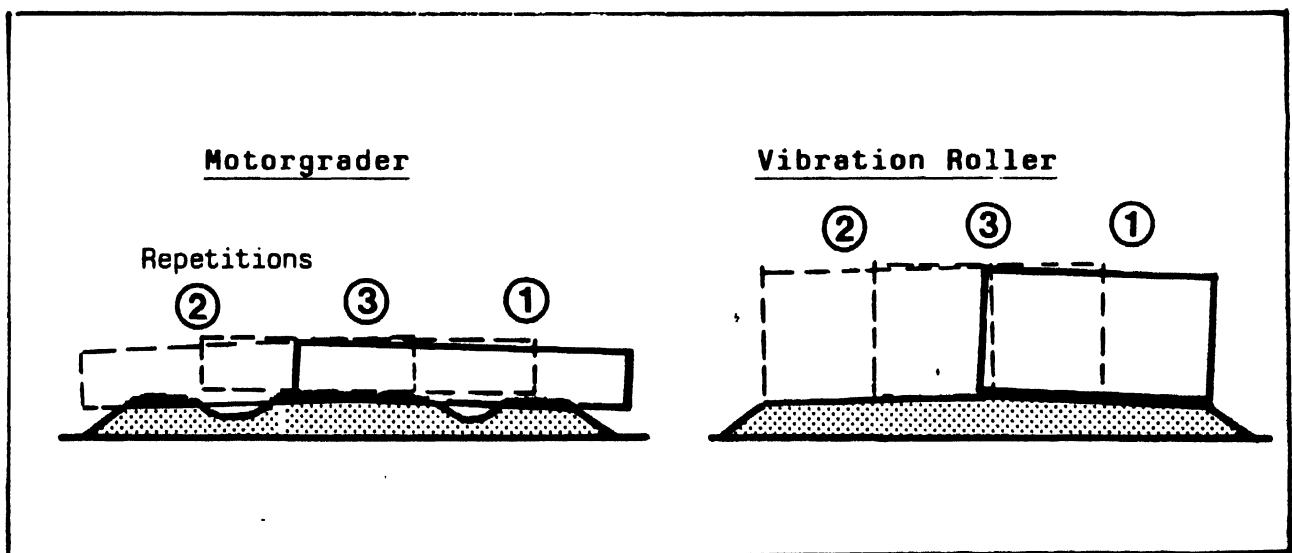


Fig. 6 MECHANIZED GRAVEL-ROAD MAINTENANCE

Open-top culverts are hindrances in mechanized road maintenance. This type of culvert has therefore been abandoned in Central Europe, in favour of surface crowning and reduced road grades.

Instead of a motorgrader, simple grader devices attached to a farm tractor or drags may be economic for minor maintenance work.

Self-propelled rollers are used to compact the restored surface course. The compaction work normally consists of three roller repetitions starting at the fill-slope shoulder (Fig. 6).

Water should be sprayed on dry surface material to get the best compaction.

The average daily production of a motorgrader and roller may be estimated at 1 to 2 km. Both machines have an annual capacity of about 200 km a year in road maintenance.

Machine costs for grading and compacting may range from US\$ 400 to US\$ 600 per kilometre.

REFERENCES

- Burlet, E. Dimensionierung und Verstärkung von Strassen mit geringem Verkehr
1980 und flexiblem Oberbau, ETH, Zürich.
- Dietz, P. et al. Walderschliessung, Verlag Parey, Hamburg and Berlin.
1984
- Hirt, R. Dimensionierung und Verstärkung von schwach beanspruchten
1974 Strassen, Vortrag Drei-Länder-Wegebautagung 1974.

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